

1N-12-TM  
179805

**NASA**  
***ENGINEERING AND TECHNOLOGY***  
***ADVANCEMENT OFFICE***

***- A PROPOSAL TO THE ADMINISTRATOR -***

N93-31312

Unclas

G3/12 0179805

NORMAN R. SCHULZE



NASA HEADQUARTERS

WASHINGTON, D. C. 20546

MARCH 28, 1993

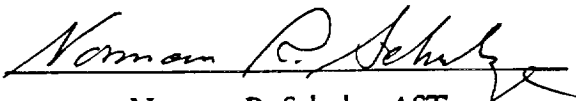
(NASA-TM-109229) NASA ENGINEERING  
AND TECHNOLOGY ADVANCEMENT OFFICE:  
A PROPOSAL TO THE ADMINISTRATOR  
(NASA) 85 p



## PROPOSAL CONTENT

This proposal has been prepared independently, off-duty, to offer a new approach to assist the implementation of NASA's mission and to resolve a long outstanding need. The contents are considered to be accurate within the bounds of assumptions as discussed in the text. Comments or questions and follow-up can be addressed to the undersigned at 202-358-0537 during duty hours or in the evening at 703-818-2328.

Prepared by:



Norman R. Schulze, AST

NASA Headquarters

March 28, 1993

Date

ii blank



## SYNOPSIS

I am proposing the establishment of an *Engineering and Technology Advancement Office* to help get NASA's cost and mission performance problems under control. These problems have created an undesired image. Further, I propose this office be empowered with the responsibility to direct the engineering application of research developed by NASA's laboratories toward practical use so as to provide a return on the investment made in NASA by the United States.

This proposal's objective is to improve NASA's mission success and cost performance and to make NASA more relevant to today's new political situation through emphasis on engineering and applied technology. The office will:

1. Develop the tools, including common-use component and system standards, to accomplish your charge to assist programs,
2. Transition technology from a research-mature status to a flight ready status and to maintain it in a state of operational readiness,
3. Promote actively the transfer of NASA's developed technology to industry in general, not just to aerospace,
4. Use industry and university resources to jointly resolve technical problems.

Over the past decade, NASA's image has been tarnished by accidents, cost overruns, and less than total mission success. Concerns about problems have caused major reviews at an increasing frequency. Problem resolution, thus, mandates major changes because past attempts to solve the deficiency - one concerning the engineering of cost-performance-applied technology, have met with less than the desired results. More important than restructuring our programs is to restructure our infrastructure.

The thesis of this proposal is simply this: our program problems are engineering problems; therefore, they require engineering solutions and proper engineering tools - not more contract monitoring and documents. We need greater in-house expertise obtained from hands-on experience to make informed, intelligent decisions while working closely with industry and universities hand-in-hand as full partners. We must provide better engineering support to our programs - NASA's life blood.

Establish for the first time in NASA's history, that which no prior review team has suggested - an office dedicated to the use of engineering and applied technology to focus on resolving technical problems and on the proper application of research-mature technology. Integrate engineering functions and applied technology across the entire Agency rather than let each program and center go their separate ways. Put into place the formal structure to assure that your challenge to perform NASA's mission faster, better, cheaper without compromising safety is achieved. Incorporate enhanced engineering inherently into all program phases: definition, development, qualification, and operations.

I recommend that you give the *Engineering and Technology Advancement Office* the opportunity to serve NASA.

*iv blank*



## EXECUTIVE SUMMARY

### NASA ENGINEERING AND TECHNOLOGY ADVANCEMENT OFFICE

**Problem:** NASA has continually had problems with cost, schedule, performance, reliability, quality, and safety aspects in programs. The Agency's image is affected. Past solutions have not provided the answers needed, and a major change is needed in the way of doing business. A new approach is presented for consideration.

**Solution:** These problems are all engineering matters and, therefore, require engineering solutions. Proper engineering tools are needed to fix engineering problems. We in Headquarters are responsible for providing the management structure to support programs with appropriate engineering tools. This proposal provides a guide to define those tools and an approach for putting them into place. Commonalty of hardware across programs is key. In the approach described herein we take the initiative rather than remain on the defensive.

---

An in-depth analysis is presented in the full text. Some key points have been extracted and placed into this Executive Summary.

---

**Background:** In the face of a rapidly changing world - one where the Cold War has ended, exports have declined, monumental increases in the national debt have occurred, and increases in personal services like health care are being demanded - NASA must reexamine its mission to assure relevance. Further, the methods by which we manage our programs - the life blood of the Agency - must be given particularly close scrutiny. Our increasing program costs, followed by overruns and schedule delays which produce less than flawless missions is, in light of the worldly changes, hardly conducive to the complete trust and confidence of the public - the source of the Agency's support.

While the above worldly changes are new, our concern about costs and overruns is not. Research into past reviews of NASA reveal that senior reviews of those issues date back to at least 1977. But the fact is: problems remain, and some even make the case, that problems are increasing. Either we have not received good advice in the past or have not followed good advice or a combination thereof. Perhaps the right questions were not asked. Consequently, significant action is mandated, the nature of which must take a different path since past solutions have not produced the results needed.

*V. Bork*

Solution: The proposed solution is to establish a NASA applied engineering organization, a new office, which is dedicated to the following objectives:

- provide engineering approaches to reduce costs and improve product quality, safety, and reliability, applicable on a NASA-wide basis,
- develop and maintain economical common-use hardware and software for all NASA programs,
- incorporate new technology into programs with little or no new risk to those programs by making research-mature hardware ready for flight application through qualification and initial flight demonstrations,
- provide engineering solutions to engineering problems using the assistance of an integrated NASA aerospace data base system to assure incorporation of lessons learned into design, test, and operations,
- establish an aggressive, efficient, and effective partnership with industry to assure that NASA's technologies rapidly transition from the laboratory to the market place.

The accomplishment of these objectives will not be easy: A cultural change will be necessary to implement this program and to effect the necessary changes. Further, the ability to accomplish any task rapidly has been lost because the Agency has become bogged down in bureaucracy.

To accomplish the aforementioned objectives, the idea forwarded herein is simply this: "don't continue to reinvent the wheel" for each new program. Incorporate lesson learned – don't continue to make the same mistakes:

Establish a new office, an Engineering and Technology Advancement Office (ETAO), to serve as a dedicated NASA-wide applied engineering management office.

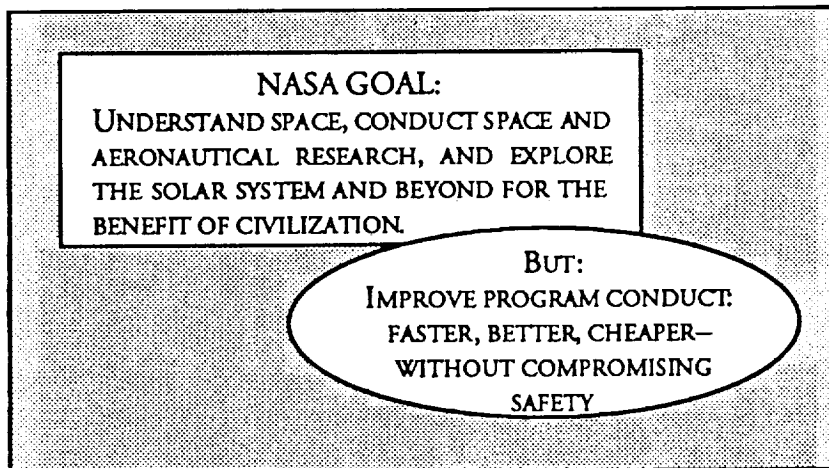
This new office is proposed to be an engineering service organization, one dedicated to the success of programs to reduce their costs. This office specializes in attending to hardware and software problems. Programs could then focus on meeting mission objectives rather than upon devoting staff and financial resources to assuring that common use components are working properly. The goal is to free the program staff from program development problems to maximum degree possible, thereby permitting them to direct more attention to the basic office mission. For unique mission components, the program offices would continue to address those developmental issues, but the ETAO could provide technical expertise to assist with problem resolution. That goal can be obtained by implementing major improvements in mission capability through reliability,

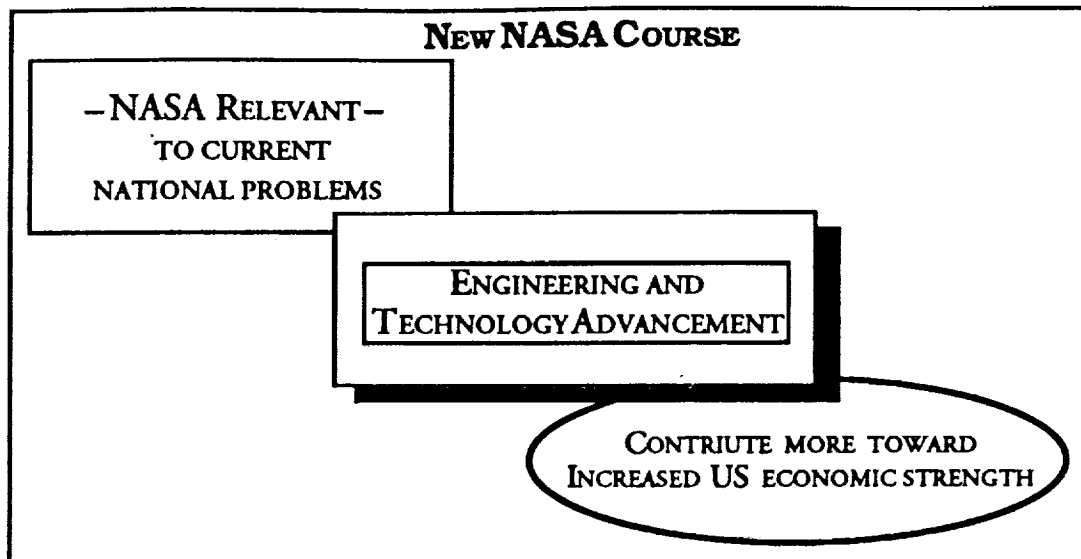


quality, new technology, operational, and safety enhancements. Further, a substantial reduction in program development and operations costs will allow the conduct of additional flight programs without any growth in NASA's budget. More can be done with less!

This program is anticipated to save a substantial amount of resources. How much is not accurately known. The initial attempt to determine savings showed that it could be on the order of \$1B to \$2B annually in comparison with the current way of doing business. But that appears to be high. The difficulty with determining dependable quantification of savings is attributed to the Agency not having budget breakdowns that are amenable to the detailed analysis required herein and certainly is beyond the ability of one individual working off duty hours. It is not unreasonable, however, to expect that the value could well be into the hundreds of millions of dollars saved. Computations and assumptions are presented in section "11.0 Costs." The maximum savings requires a successful, fully implemented Engineering and Technology Program. The economic benefit transcends NASA programs because the concept behind this proposal addresses, in part, a great need nationally to face, viz. the issue of applied technology. Engineering and applied technology are essential partners for opening new markets in order for the United States to maintain its economic strength in the wake of the Cold War's end and from increasing international competition.

NASA's goals and the suggested new direction are stated below:





NASA's programs in this proposal are considered to be the means to accomplish NASA's goals rather than the end objective. Hence, we direct our attention to a new management process which streamlines program development and manufacturing, and perhaps operations, such that NASA attains a higher level of program management efficiency. Streamlining the procurement process is also important to reducing costs, but that is a topic beyond the scope of this proposal. This proposal is, thus, forwarded with the intent that NASA will be in a position to more successfully accomplish its mission at reduced cost and risk. The means to that end is achieved through the advantages offered by leveraging commonly engineered and developed system components and subsystems, including both hardware and software. This proposal, consequently, places resource emphasis on the purpose for NASA rather than on the development of the components and systems which are simply the tools of the trade used to attain NASA's goals.

Merits of the solution: A dedicated NASA engineering office is a new approach for solving generic engineering problems. Office responsibilities include: collection of technical lessons learned and the incorporation of that experience base into subsystem designs and processes via well-planned, systematic design, test, and manufacturing approaches. Thus, the office will produce flight-ready hardware for common use across all NASA programs without redesign and requalification. That hardware then becomes a "Standard." As research-mature hardware and software are made available, they, too, will be subjected to the same rigor to assure flight readiness for flight program use.

Lessons learned methodology currently consist of scattered documents, numerous data bases, and much data in the minds of senior experienced officials. But lessons learned is a powerful cost-cutting engineering tool. With proper implementation, we are in a position to focus on key specific issues: What exactly

are the Agency-wide engineering problems and how are they best fixed? The office deals with technical facts and engineering solutions to resolve technical problems. The ETAO would provide technical consistency across all NASA centers. We avoid having each new program conduct wasteful, unnecessary qualification programs – the past and current practice. Waste avoidance is accomplished through the use of commonly designed and qualified hardware which can be made ready for immediate use by programs. The ETAO integrates applied technology and applications of common hardware/software across all NASA programs for common benefits. No longer will it be necessary for programs to continually design-redesign, develop-redevelop, and qualify-requalify that common use hardware and software. The ETAO performs cost, schedule, safety, and reliability engineering, in conjunction with performance engineering, to assist NASA in resolving key engineering issues. This is a systems approach. Optimal component performance may not necessarily be optimum overall for the intended program.

The office is proposed to be managed by senior experienced engineers at Headquarters, and the program is implemented by civil servants at the Field Installations who acquire hands-on experience in the process.

Why is this approach expected to work?

Take a look at the GAO study results (from page 34 in the text of the proposal):

|  | CAUSES FOR PROGRAMS EXPERIENCING COST CHANGES |                      |                   |                     |               |                     |
|--|---|----------------------|-------------------|---------------------|---------------|---------------------|
|  | Program redesign                              | Technical complexity | Budget constraint | Inadequate estimate | Shuttle delay | Inflationary effect |
| Number of programs experiencing cause for cost increases | 15  | 16                   | 12                | 11                  | 9             | 16                  |

This approach will directly assist alleviating all of the above causes of cost problems identified except for the latter two. Even for those two the belief is offered that with a properly implemented engineering and applied technology program, the opportunity for future “Challengers” will “strikingly” diminish. Challenger and inflation are interrelated causes. So, in reality, we can expect that all of the above causes are addressed herein!

Bottom Line:

|   |
|---|
| Program cost = \$ basic hardware + \$ software + \$ risk reduction + \$ overhead/fees |
|---|

$$\boxed{\$ \text{ hardware } + \$ \text{ software } = \sum (\$ \text{ design } + \$ \text{ development } + \$ \text{ qualification } + \$ \text{ manufacturing })}$$

Program costs are fundamentally determined from the sum of: hardware/software costs, risk abatement, i.e., the degree which we wish to assure that mission success will be achieved through redundancies, special tests, analyses, etc.), along with program overhead/fees. The design, development, and qualification of generic hardware and software for use across NASA will reduce costs. New research mature technology which has been properly flight qualified will also reduce costs and enhance safety, reliability, mission success, and operations.

Principle implemented: To achieve the end objective of less costly and more successful programs, we establish a management system that implements "Standard hardware and software" to the maximum extent possible. Programs will be in a position to design to meet the performance from available Standards, or they can accept small performance and mass compromises, if necessary, in order to reduce schedule risk, enhance reliability, and effect program cost reductions. With a reserve of Standard hardware, waste which results from the purchase of spares, and which can cause expensive program delays due to the lack thereof, can now be avoided, thereby effecting additional significant savings.

A "Standard" refers to common-use hardware or software that has been broadly qualified to meet a wide range of NASA's mission requirements such that the Standard can be obtained off-the-shelf or by procurement from a vendor, or vendors, which have been certified to produce the Standard. A true NASA Standard approach has never been implemented, although an effort was commenced approximately 20 years ago. The Standard, by definition, has been qualified to meet a wide range of mission requirements. It can be used directly on a wide variety of programs without requalification. The important point is that the Standard has a frozen design and a frozen manufacturing process, both of which are essential to maintain qualification status. To implement the program, wide use of civil servants is proposed, the objective being to provide for the much needed hands-on experience. From that experience, NASA becomes an educated buyer, a strong tool for effecting future cost reductions.

To the skeptics of Standards, the question must be asked, "Would you be willing to pay the price for customized software for each application on your personal computer at home?" The answer obviously is, "Of course not; I could not afford it!" "Would you prefer to pay for customized, single supplier headlights for one's automobile or any other non-standard part?" The list goes on and on, and the reply is no different. Or alternatively, "Would you prefer the price advantage offered by the two standard headlight designs that already exist?" The reply is

clearly, “Yes.” So why should we ask the public to pay customized prices when we would not do so for our own use, if there is an option? Major companies and the DOD successfully use standards, so there must be a lesson from a profit motivated world on how they do business more cheaply or from an operations-oriented government organization. This proposal would make that option available.

NASA’s options are to: (1) stay the course, (2) change to an integrated, focused engineering/applied technology system (including Standards), or (3) change to the opposite – give greater latitude to program individuality and further separate common program hardware used throughout NASA. The role of the engineer in the first has been primarily one of contract monitoring, whereas in the second, real technical skills are developed. In the third, engineering is reduced to one of even further contract monitoring, more than already exists under option (1) – a contributor to the current problems. The second option allows us to determine our fate and makes the NASA engineering staff an educated buyer; the third option places our fate in the hands of others. Forget not: NASA in the end is responsible for its programs – not the contractors.

Benefits: The proposed office changes the concept of “customer” to a more general and widely applicable definition. The customer of the ETAO consists of all NASA programs through the integration of technological tools used by the major Agency disciplines. Science programs and launch systems are customers. The Space Station Program could have been a great beneficiary from the implementation of common use equipment. In view of the latest redesign, it is not clear how timely the ETAO could be, but if this ETAO had been an on-going activity at program start, the opportunity for commonality of components is great. Savings to NASA would have been correspondingly great.

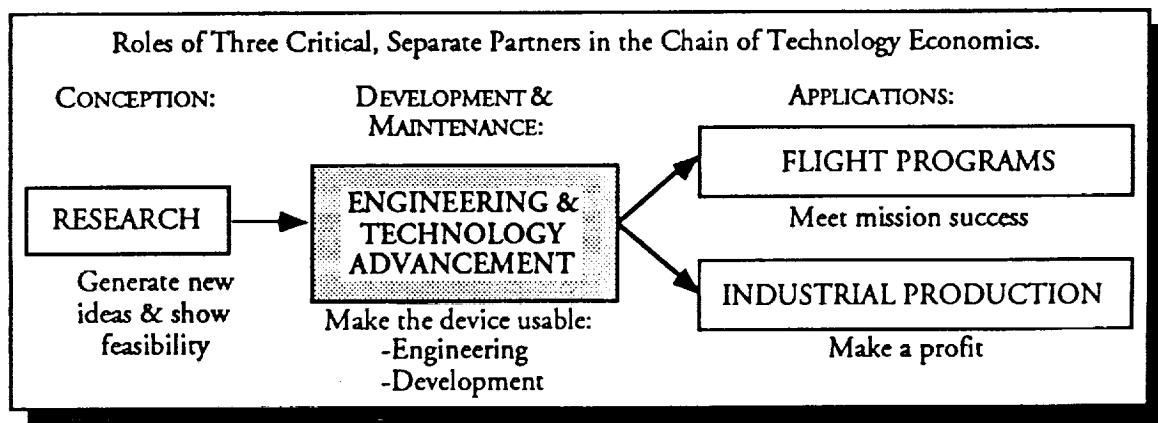
Next, intercenter cooperation becomes a necessity as requirements and results are worked jointly. The ETAO assures current up-to-date hardware through a Product Improvement Program. All four program phases, Phase A through D, are aided by this initiative, because program management teams will know the availability of components/subsystems and their performance capabilities. This is particularly important for Phase A and B studies by providing an engineering tool for program teams to develop more realistic cost estimates, risk factors, and performance capabilities. From better predictions, NASA gains in credibility.

But the ETAO extends beyond the NASA environment by actively promoting its technology resources. The objective is to increase the United States’ economic position in an ever increasing international competitive market. The ETAO provides the organization to that end. From that organization, applied technology becomes a significant force contributing to industry as a partner and by working

with universities to continuously improve upon engineering and technology methods and principles.

This approach respects the distinction of, and attaches great importance to, the separate roles that research and engineering/applied technology play in the NASA system. The ability of NASA to maintain a strong research role is absolutely crucial to the future of the country. Today, this is an even more important statement than in the past because the first casualty of a tight economy is almost invariably research. Research is on the retreat. Without research we sacrifice the future for the short term gain. The ETAO should be run as a business. It must make a "profit" or go out of business. Research is different. It is special in that ideas and the conception of new thoughts cannot be priced. Research, thus, cannot be run as a business.

So we must look beyond the short term. Research, engineering, and the use of engineering and applied technology by NASA's programs and industry comprise a triad partnership as shown below. Each demands a separate management identity to best focus on and to service their individual functions:



Conclusion: This document presents an integrated engineering approach to solve engineering problems. The key to the successful accomplishment of programs in a streamlined manner is to provide the proper management organization that serves as the tool to implement applied technology. Never has there been a NASA organization which provides a service-oriented, applied engineering focus on the identification and resolution of common technical issues across NASA. Technical problems and cost increases will continue unnecessarily to the detriment of all NASA programs, without such focus as provided by an integrated NASA engineering approach to technical problem resolution.

Prior approaches and efforts have been unsuccessful at resolving engineering problems and technology transfer. A new approach must be tried.

The implementation of this proposal is essential in carrying out NASA's 21<sup>st</sup> century missions. There must be a new way of doing business. Change is mandated. We cannot afford to continue the conduct of programs in the old way. This proposal requires a change in the culture to implement. Strong participation with industry and academia as a customer-oriented system is essential for the economic survival of all parties.

In the end it is better that we be viewed as having recognized our problems rather than to have brushed them aside, and to have taken positive identifiable actions to remedy the ills rather than to take meaningless paper actions to close out actions. The feed-back system is mandatory. This is a closed-loop feed-back operational system. That then would describe to the reviewers of our budget – the Congress – the degree of the seriousness which NASA places upon resolving our problems.

Recommendations:

- 1.) Proceed with a program definition task to implement an Engineering and Technology Advancement Office (ETAO): Assemble an *Engineering and Applied Technology Working Group* having representatives from each center to establish and plan the office and to further establish a budget. Conduct a program budget study to determine the potential savings from the ETAO, which in turn will establish the resource level that should be committed. Establish goals and a means to verify progress on those goals. Using a staff of 2-3 Headquarters engineers, initiate several pilot Standard demonstrations, ones that can produce quick results. By the end of the first year, complete an Engineering and Applied Technology Strategic Plan for senior management review. By the end of the second year, complete the determination of NASA's requirements for establishing program priorities and complete a pathfinder Standard.
- 2.) Establish responsibilities in the ETAO to include:
  - a.) NASA-wide Standards, including a Product Improvement Program and configuration management system,
  - b.) a low risk system to transition research-mature technology to flight program status,
  - c.) a system to rapidly transfer applied technology from the laboratory to the market place.

DELIVER PROGRAMS. ON TIME. ON COST. ON PERFORMANCE AND SERVE THE AMERICAN INDUSTRY AND UNIVERSITIES AS PARTNERS.





TABLE OF CONTENTS

|   |     |
|---|-----|
| Proposal Content  | iii |
| Executive Summary   | vii |
| Endorsement   | xix |
| 1.0 Introduction  | 1   |
| 2.0 NASA Goal   | 3   |
| 3.0 Proposal  | 4   |
| 5.0 Definition of Terms   | 10  |
| 6.0 Method to Achieve the Goal  | 11  |
| 7.0 Analogy   | 21  |
| 8.0 Analysis of Problems, Historical Issues and Resolution, Benefits      | 22  |
| 8.1 Analysis of Problems  | 22  |
| 8.2 Analysis of Prior Reviews of Issues and Resolutions Forwarded to NASA | 26  |
| 8.3 Benefits  | 39  |
| 9.0 Spin-offs   | 44  |
| 10.0 Discussion   | 46  |
| 11.0 Cost Benefits to Programs  | 53  |
| 12.0 List of Candidate Items for Standards                                | 60  |
| 13.0 Functions and Priorities   | 61  |
| 14.0 Options  | 63  |
| 15.0 Accountability   | 64  |
| 16.0 Recommended Next Steps   | 65  |
| 17.0 Summary  | 66  |
| Appendix A  | 68  |



## ENDORSEMENT

Individuals having a broad background and a wide diversity of viewpoints have reviewed this proposal which was commenced in late November 1992. Those individuals are located within NASA – at Headquarters and Field Installations, other government organizations, and in industry. While this is an issue such that agreement on all concepts proposed was not reached, many aspects were. Section 10 presents the major issues and a discussion of each.

Some events may have changed since the original undertaking (November 1992) or may be undergoing change about which information may not be readily available. Thoughts contained herein may or may not be covered by the various reviews underway. The information may be of assistance in any such new undertakings, and the proposal is submitted as such.

The constructive comments made by the many reviewers are gratefully acknowledged and are very much appreciated.

The conclusion reached was to proceed with submittal, with the desire that the information provided herein will provide additional perspectives, analyses, focus, new ideas and approaches to assist NASA with enhancing its mission.

PRECEDING PAGE BLANK NOT FILMED

xviii blank





## 1.0 INTRODUCTION

The United States aerospace program conducts missions necessary to understand the universe, colonize space, advance aeronautics, help assure the pre-eminence of the aerospace technology health in the United States, and address social problems – such as environmental issues – in so far as such problems can be addressed through aerospace technology. Missions range from aircraft operation in the atmosphere, to understanding the Earth's environment, to explorations of other planetary bodies within the solar system, and beyond the solar system out to the edge of the universe. Like any governmental research organization, NASA also has the obligation to enhance the United States economy. Thus, public faith is retained, and the public's investment is returned. Public faith results from safely conducted on-time, on-performance, and on-cost programs. The return results from new business produced by technological advancements, regardless of whether or not the technology is related to the assigned area of governmental expertise. The benefits that can result from close cooperation between government and business is underscored by the success that the Japanese have enjoyed.

NASA, chartered with the conduct of the peaceful exploration of space and the conduct of aeronautics programs, has basically enjoyed good public support throughout its entire career which commenced in 1958. These programs have been conducted under 3 major program offices – research, human/automated space flight vehicles, and science (since 1961) – over the 35-year history. The issues which NASA brings forward and their resolutions are indeed important to the future of the Earth and to the continued prosperity of the United States. In that light our programs assume monumental proportions; and, hence, the successful and safe conduct of these missions is a top management priority.

The realities of the present require that NASA now reexamine its traditional role. NASA, born under the Cold War environment, must seek new opportunities to expand service to the United States public. These realities include the new problems which now face the United States economy. The space program's budget must compete with high ranking priorities such as health care, reduction of the deficit, and balance of trade issues. Further, an international competitive economics condition now exists with which the United States aerospace industry previously did not have to contend. The space program is 35 years mature; hence, we understand the space operational environments and the requirements which must be fulfilled to better meet near-term program success. We can do things differently. In fact, in view of all of the above, we can no longer operate with business as usual.

The perspective of those new variables require the review of our operation because we in NASA are now affected by costs to a degree that has never previously existed. Mission failures and cost overruns will, in particular, create a threat to NASA's aerospace mission beyond any that has previously existed.

While NASA has enjoyed strong public support, there have been two exceptions, however, where that support waned which are worthy of note in the light of today's environment. Strong public support decreased or questions arose concerning the wisdom of NASA's programs when two events occurred: a slowdown in the economy such as experienced in the early 1970's and, secondly, when programs encountered cost overruns or major failures. We are encountering both situations now. Program costs and program results are, thus, criteria to be dealt with by NASA more aggressively than ever.

This proposal's objective, then, is to achieve the desired mission results, safely and within budget. That objective mandates a change in our culture and operation – the subject of this applied engineering technology proposal.

Applied technology transcends NASA's mission in importance. There is concern that the United States is critically lagging Europe, Russia, and Japan in advanced development as discussed in a recent article in *Washington Technology*<sup>1</sup> and as reported in a NSF/NASA study<sup>2</sup>. While this proposal will not resolve that larger national issue, we in NASA are a part of the technology issue; and the implementation of this proposal, or equivalent, would demonstrate the importance that NASA attaches to applied technology. The implementation, thus, is a major step which needs to be undertaken to maintain a world power status in aerospace. The program would serve as a technology model, and clearly show NASA's leadership in addressing current issues affecting the economic well being of the United States, particularly with the use of applied technology to assist in providing a sound economic future.

## 2.0 NASA GOAL

The purpose of NASA programs has been to benefit the United States through the conduct of programs for space science, space and aeronautical research, and the exploration of the solar system and beyond. The NASA-wide goal, Fig. 1, is to improve upon the conduct of those programs (faster, better, cheaper) without compromising safety, or preferably, with improved safety.

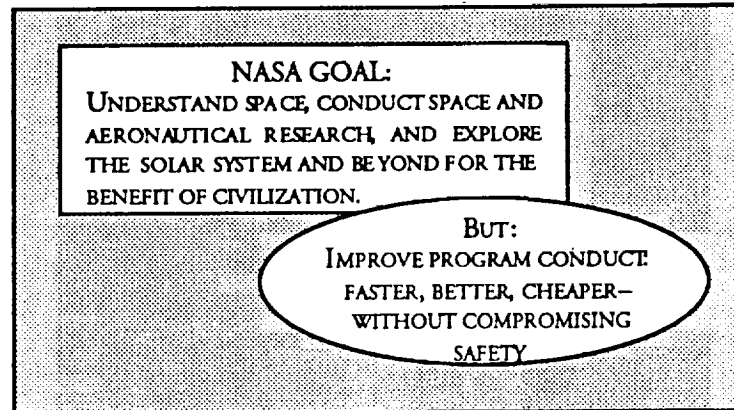


Fig. 1. NASA-wide goal.

A new goal, Fig. 2, is to assist actively the United States in strengthening its economy through assets as provided by applied technology.

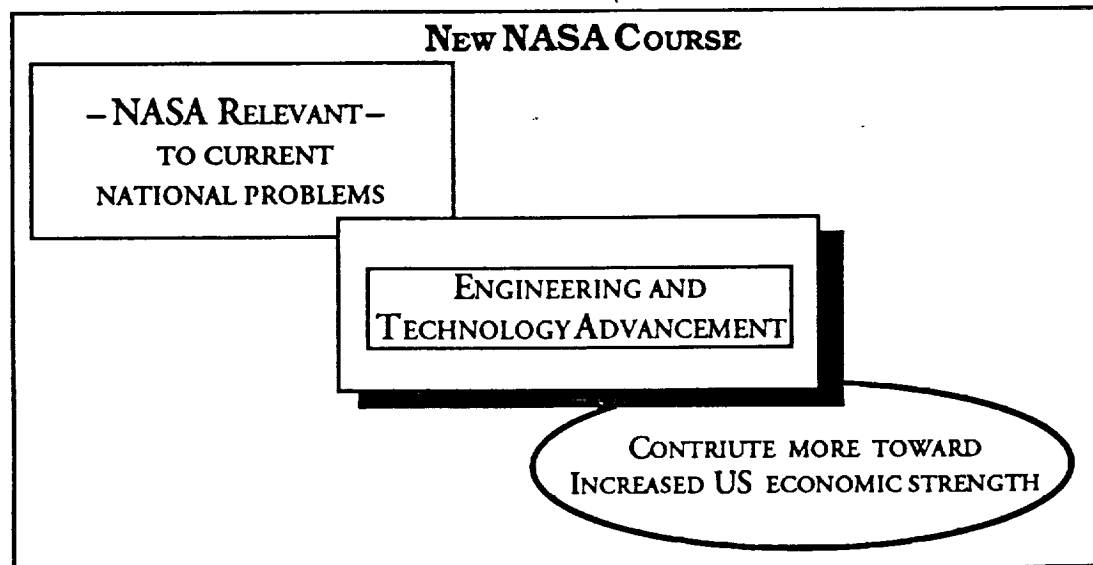


Fig. 2. Engineering and Applied Technology-industry goal.

### 3.0 PROPOSAL

Provided herein is a proposal for a management approach by which the above goal can be implemented through (1) a more accurate program definition phase and, most importantly, (2) during a program's developmental phase. Furthermore, this approach provides NASA with (3) an opportunity to enhance program operations through technology. The purpose of this proposal is, thus, to increase the safety, reliability, and quality of NASA missions at a substantially reduced cost. The first question is, "How does one obtain more, using less total resources?" The second is, "How do we reach out and impact the United States industry with our technologies?"

Because NASA's programs in this proposal are considered to be the means to accomplish NASA's goals rather than the end objective, we direct our attention to forward a management process which will streamline future programs such that we attain a higher level of efficiency in the conduct of programs. This proposal is, thus, forwarded with the intent that the Agency can better accomplish its mission – the conduct of science, aeronautical/space research, and space exploration – through the advantages offered by leveraging commonly developed system components and subsystems, including both hardware and software.

This proposal, consequently, places resource emphasis on the purpose for NASA rather than on the development of the components and systems which are simply the tools of the trade used in the attainment of NASA's goals.

*Key to the successful, cost effective, and efficient accomplishment of programs is the establishment of a new management organization which has an engineering-applied technology charter as its sole responsibility.*

NASA has throughout nearly its entire history maintained offices devoted to research, space launch - human and automated, and science but never one dedicated to the tools of the trade – engineering and the application of technology to those programs. The omission has caused serious problems. Those problems prompted the preparation of this proposal. This proposed office will fill that void by providing an applied engineering focus across NASA. Without that focus, technical problems and cost increases can be expected to continue. The relationship between the four organizations is depicted in Fig. 3.



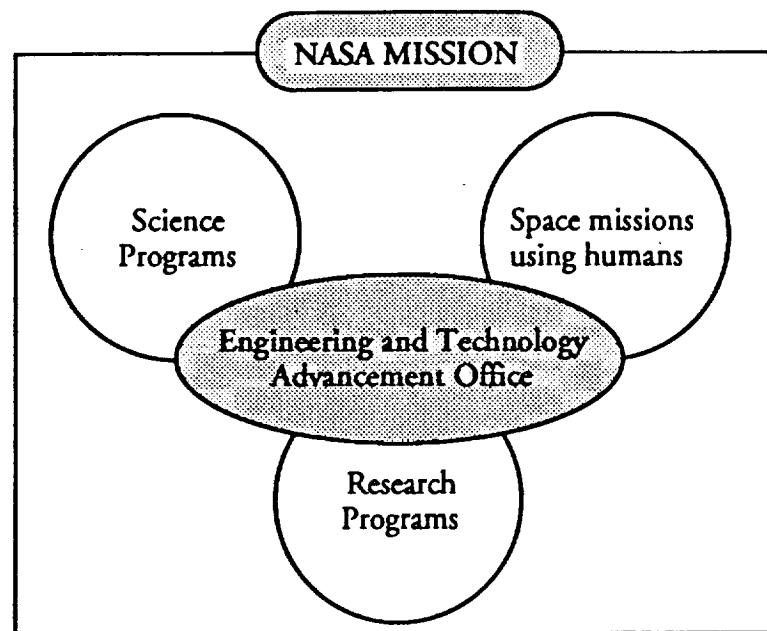


Fig. 3. Relationship of ETAO with current organizations.

This proposal, in essence, offers for NASA's consideration a hardware/software reliability, quality, and safety technology engineering program, including applied technology transfer closely coupled to industry, to address many of the root causes of technical problems experienced by programs. Hence, we address under one solution the answer to both questions raised earlier.

This is a new program emphasis for the safety, reliability, and quality role. Conceptually, this proposal evolves well beyond the approach which we have traditionally used since the formation of NASA, i.e., the reliance on inspection to provide quality/reliability. This proposal vectors resources toward a system which is one of inherent design understanding through the active management of engineering and technology. From the effective implementation of inherent design understanding, we achieve inherent safety, reliability, and quality.

The formation of an Engineering and Technology Advancement Office (EATO) is suggested to serve as a critical management tool in performing the following Agency objectives to assist with meeting the NASA goal:

- the conduct of programs on schedule by assuring that:
  - for the purpose of planning and trade studies, at the Phase A program definition level, well-defined hardware and software characteristics are established, UP-FRONT, with quantified performance characteristics over a wide range of operational regimes to permit improved accuracy in the analyses performed by the program offices,
  - for the commencement of Phase B, well-defined hardware and software which are readily available with performance well established as advertised, thereby, providing hardware with a well defined pedigree,
  - co-shared requirements, hardware qualifications, and manufacturing replace individualism which result in the unnecessary expenditure of resources;
- meeting mission specification requirements through:
  - high quality products,

- high reliability system elements;
- the completion of programs within cost targets (or living within cost constraints);
- the provision of a very cost-effective method for incorporating new technology into programs as research mature technology becomes available. Hence, we assure that the best performing equipment is available to meet new mission objectives at an acceptably low risk level for use by NASA program managers;
- reductions in operational costs through technology enhancements and standard, common use designs with the proper design standards developed for the sound conduct of programs;
- reduction in program life cycle costs, including termination factors such as disposal, in an environmentally technically acceptable manner; and
- a positive, active means to reach out to the entire American industry and small businesses with new technology.

The proposal, thus, concerns as a primary objective, the development of a process whereby mission safety and reliability will be assured at reduced cost, and that we can broaden our horizons beyond the aerospace industry.

To accomplish the foregoing NASA-wide goal, the proposal is made herein to establish an Engineering and Technology Advancement Office (ETAO) as a service organization to assist programs.

In this engineering and technology initiative we provide the tools for the engineering trade – not the trade. The Engineering and Technology Advancement Office does not perform full system analyses and manage programs such as launch vehicles and mission platforms. What it does is develop common-use hardware and software for use by programs in complete flight systems. Those systems remain, of course, the responsibilities of the program offices now as they always have been. The Engineering and Technology Program is a service to those organizations to assist them with improved planning and through the availability of flight qualified components and subsystems. An Engineering and Technology Program will be developed under the auspices of the ETAO. The emphasis of this proposal is not so much on the program, but on the problems in need of resolution and on development of rationale why this office is considered the proper solution. The only vestiges of program content is presented in sections 12 and 13.

The importance of the engineering and technology role is sufficiently great that a separate organization is warranted. Place this function within one devoted to research, or one devoted to program development, or one devoted to operations, and the competition for resources will result in one or the other functions decreasing in importance. A single office to conduct all of NASA's engineering and applied technology will be the most cost-effective management approach. Through interdependent common requirements on an Agency-wide basis, it integrates the

currently splintered program development activities which will result in major savings. Engineering and applied technology transcend program boundaries.

Engineering and applied technology are of such great importance that a dedicated organization is considered essential.

Key features and responsibilities of the ETAO are presented in Fig. 4.

| KEY FUNCTIONS:<br>ENGINEERING AND TECHNOLOGY ADVANCEMENT OFFICE  |
|--|
| <ul style="list-style-type: none"><li>• MAINTAIN CURRENT TECHNOLOGY, INCLUDING STANDARDS.</li><li>• TRANSITION RESEARCH MATURE TECHNOLOGY INTO FLIGHT QUALIFIED AND PROVEN STATUS.</li><li>• MAINTAIN NASA-WIDE DATA BASE OF LESSONS LEARNED. A PRODUCT IMPROVEMENT PLAN (PIP), USING THAT DATA BASE, WILL PREVENT RECURRENCE.</li><li>• DETERMINE COMMON DESIGN AND TEST TECHNIQUES TO ASSURE HIGH QUALITY AND HIGHLY RELIABLE PRODUCTS.</li><li>• SUPPORT FUTURE PROGRAM COMMON USE NEEDS, MANAGE ENGINEERING DISCIPLINE TO PROVIDE PROJECTIONS AND STRATEGY FOR KEEPING A STRONG AND PROPERLY FOCUSED ENGINEERING DISCIPLINE.</li><li>• MATCH POLICIES AND GOALS WITH ENGINEERING TALENT REQUIREMENTS, INCLUDING TOOLS SUCH AS UP-TO-DATE FACILITIES AND EQUIPMENT.</li></ul> |

Fig. 4. Key functions of the Engineering and Technology Advancement Office.

These functions and responsibilities are presented in greater depth in the proposed charter below (fig. 5).

## CHARTER

The Office of Engineering and Technology is responsible for implementing the following functions:

### A.) CURRENT TECHNOLOGY:

1. Determining NASA's needs for specific common elements of hardware and software across all programs.
2. Developing a NASA-wide list of prioritized common components and systems.
3. Developing a reasonable set of specifications for defining common "Building Blocks" of hardware and software that are to be used across the Agency's programs – referred to herein as "Standards".
4. Determining the availability of the hardware and software which are expected to meet the specifications.
5. Developing Standard hardware/software which meet NASA's programs' needs:
  - a. Conducting the developmental and qualification testing of Standards to meet a wide range of NASA's mission requirements.
  - b. Performing first demonstration of Standards in flight or other intended applications.
6. Educating the development centers on the availability of the resources and to receive their inputs for ways to improve the system to be fully supportive of their needs.
7. Maintaining the Standards and a lessons learned data base of experience to correct technical problem areas – a Program Implementation Program (PIP).
8. Providing and maintaining a list of qualified suppliers from which the Standards can be procured or, alternatively, which can be directly obtained from a depot.
9. Maintaining the Standards, including storage.
10. Coordinating a NASA-wide Standards program through steering-advisory committees which include all centers in order to assure completeness of requirements and acceptance of the Standards.
11. Coordinating with other government organizations and industry to include their inputs.
12. Strategic use of university resources to assist with the achievement of the desired results.

### B.) RESEARCH-MATURE TECHNOLOGY:

1. Identifying the candidates for Standardization.
2. Establishing that the benefits provided to programs have validity and prioritize, in conjunction with the user organization, implementation schedules to meet program needs.
3. Qualifying designs for flight.
4. By using one of several strategic options, demonstrating that the new technology will perform in the space environment within expected performance limits:
  - (a) deliver flight qualified units and fly concurrently with a back-up built to current technology;
  - (b) use the Standard as backup;
  - (c) fly the Standard as an experiment without it having an active role in the function of the spacecraft.
5. Proceeding as in topic A. above, once demonstrated.

(Con't.)

Fig. 5. Charter of Engineering and Technology Advancement Office.

CHARTER (CON'T.)

C.) NASA ENGINEERING SUPPORT:

1. Maintaining a continuous Product Improvement Plan to assure that costs, quality, and safety issues in all program phases – development through termination/disposal – are being actively addressed through technology solutions.
2. Addressing technology solutions to assist programs with life cycle issues ranging from design, development, manufacturing processes, operations, and disposal, including documentation (the paperwork associated with design specifications, requirements, testing, etc.).
3. Developing improved test techniques.
4. Conducting efforts to obtain understanding of manufacturing processes of Standards.
  - Performing modeling of the Standards design and manufacturing processes to determine critical processes necessary for control in order to produce highly reliable products.
  - Conducting test verifications.
5. Addressing reliability performance technology issues concerning long duration missions, those having mission life times of at least 20-25 years and beyond for planetary missions and for those beyond the solar system:
  - Establishing design techniques such as the design of "solid state" components.
  - Establishing test techniques to qualify Standards for long-duration missions.
7. Determining design and test techniques to assure high quality and highly reliable products.
8. Establishing and validating accelerated test techniques.
9. Providing understanding of important design, test techniques, and process aspects of critical hardware which may not be used sufficiently to warrant its development as a Standard.
10. Developing strong systems engineering capability.
11. Integrating "cost, schedule, safety, reliability engineering" with performance engineering.
12. Establishing America's technology needs and marketing NASA's engineering and applied technology to assist with meeting that need.
13. Serving as a resource for independent technical expertise for programs to assist program managers with technical and cost analyses for supporting program-critical decisions and to provide a peer review resource. The independent technical support includes the conduct of independent failure investigations and recommended resolutions.
14. Sponsoring technical workshops to assure divestiture of results to industry and to receive customer inputs.
15. Providing for the development of hands-on NASA expertise.
16. Managing NASA's engineering discipline to provide projections and strategy for keeping a strong and properly focused engineering discipline, one which matches policies and goals with talent requirements, including the tools such as up-to-date facilities and equipment, to support future needs. Participation with universities is important to provide mutual support.
17. Serving as a strong interface with United States industry in general, not just the aerospace industry, particularly with transferring technology to all commercial sectors, not just aerospace.
18. Working cooperatively with professional societies and industrial associations to spread applied technologies.

Fig. 5. Charter of Engineering and Technology Advancement Office (con't.).

The implementation of this proposal is considered to be essential in carrying out NASA's 21<sup>st</sup> century missions. There must be a new way of doing business. Change is mandated. We cannot afford to continue the conduct of programs in the old way. This proposal requires a change in the culture to implement. Strong participation with industry and academia as a consumer-oriented system is essential for economic survival of all parties.

## 5.0 DEFINITION OF TERMS

A program may be considered to have three major basic phases: program definition, the development phase, and an operational phase. In the program definition phase, mission objectives are defined and system requirements determined; options are evaluated with a preliminary design completed. In the development phase, the design is finalized, the hardware manufactured, and qualification tested to meet mission objectives in the intended operational environment. The system is then brought on-line for use in the operations phase.

This proposal provides a technology focus which is based upon an approach to produce improvements in all three phases. This proposal aids the definition phase by making available the precise knowledge of component/subsystem performance capabilities and costs, so that a more realistic program can be better prepared early in the definition phase. But we also aid the operational phase of programs, to the extent that operations can be enhanced by developmental phase technology, a potentially substantial contribution.

For purposes of this proposal we consider a system to comprise both hardware and software. Hardware may be in either one of two categories, that which is currently in use or alternatively, that which is research-mature but lacking in operational functionality. We address both categories. In many cases throughout the proposal, the term hardware is used, but software is also normally implied.

A "Standard" refers to common-use hardware or software that has been broadly qualified to meet a wide range of NASA's mission requirements such that the common-use elements can be obtained off-the-shelf or by procurement from a vendor, or vendors, which have been certified to produce the Standard. The Standard by definition has been qualified to meet a wide range of mission requirements. It can be used on a wide variety of programs without requalification. The important point is that the Standard has a frozen design and a frozen manufacturing process, both of which are essential to maintain qualification status.

## 6.0 METHOD TO ACHIEVE THE GOAL

To accomplish those aforementioned objectives, the idea forwarded herein is simply this: "don't reinvent the wheel" for each new program. Incorporate lessons learned – don't continue to make the same mistakes. That is, incorporate a new office, an Engineering and Technology Advancement Office (ETAO), into the NASA management structure to serve as a dedicated NASA-wide applied engineering management office.

A dedicated NASA engineering and applied technology office would be a new approach to solving generic engineering problems. Central responsibility for the collection of technical lessons learned would reside in that office. And that office would be responsible for incorporating the experience base into subsystem designs and processes via well-planned, systematic space design, test, and manufacturing approaches. The lessons learned methodology currently comprises scattered documents, or else they reside in the minds of senior experienced officials. In this program we now implement a definitive program to actively address this important issue. From lessons learned, we are in a position to focus on the specifics: What exactly are the problems and how are they best fixed? The office is to deal only with technical facts. The ETAO would provide technical consistency across all NASA centers. We avoid having each new program conduct wasteful, unnecessary qualification, and often parallel, programs – the past, and current, practice. Technical consistency is accomplished through the use of commonly designed and qualified hardware. The ETAO coordinates usage across all NASA program offices for the common benefit of technology to programs.

That is, the bottom line is:

*Program costs are fundamentally determined from the basic, required hardware/software costs, plus the degree which we wish to assure that mission success will be achieved (risk reduction: redundancies, special tests, analyses, inspections, assurance, etc.), along with program overhead/fees. Generic hardware and software which has been designed, developed and qualified for broad use across NASA will focus on specific applications to address generic technical problems. Problems addressed generically will have had integrated into their design lessons learned which are based upon Agency-wide experiences. Hence, the ETAO extends its sphere of influence beyond the narrow bounds of individual program limits. Accordingly, costs will be expected to decrease. New technology which has been properly flight qualified may also reduce costs and enhance safety, reliability, mission success, and operations.*

And the principle employed is that:

*To achieve the end objective of less costly and more successful programs, a management system is established that implements "Standard hardware and software" to the maximum extent possible. Programs will be in a position to design to meet the available Standards or accept small performance and mass compromises, if necessary, in order to reduce schedule risk, enhance reliability, and effect program cost reductions. With a reserve of Standard hardware, waste which results from the purchase of spares, and which can cause expensive program delays due to the lack thereof, can now be avoided, thereby effecting significant savings.*

The current approach to programs and the new proposed approach are presented in Fig. 6 and Fig. 7 respectively.

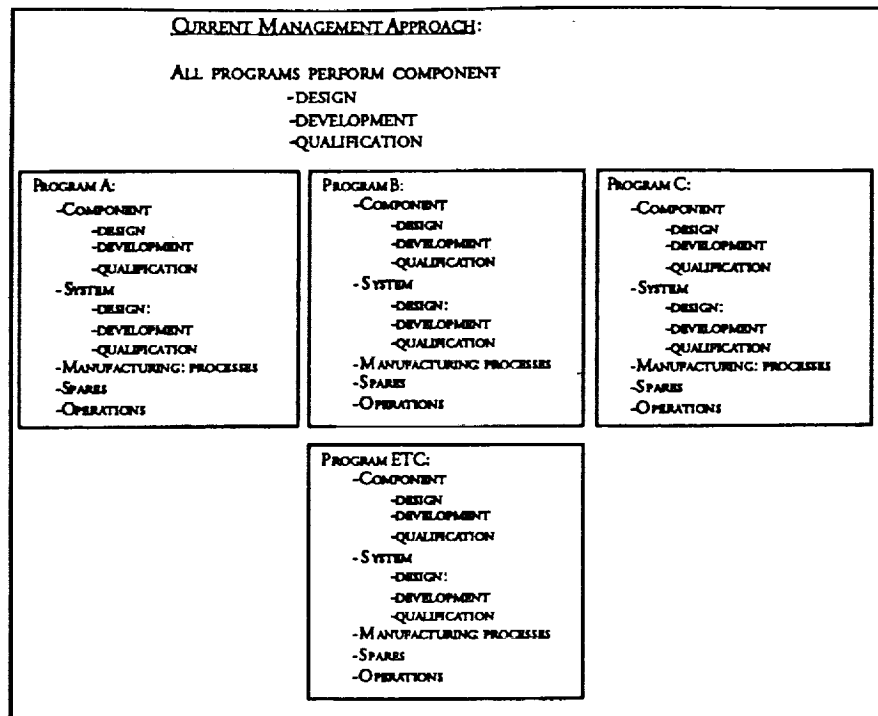


Fig. 6. Current approach to programs.

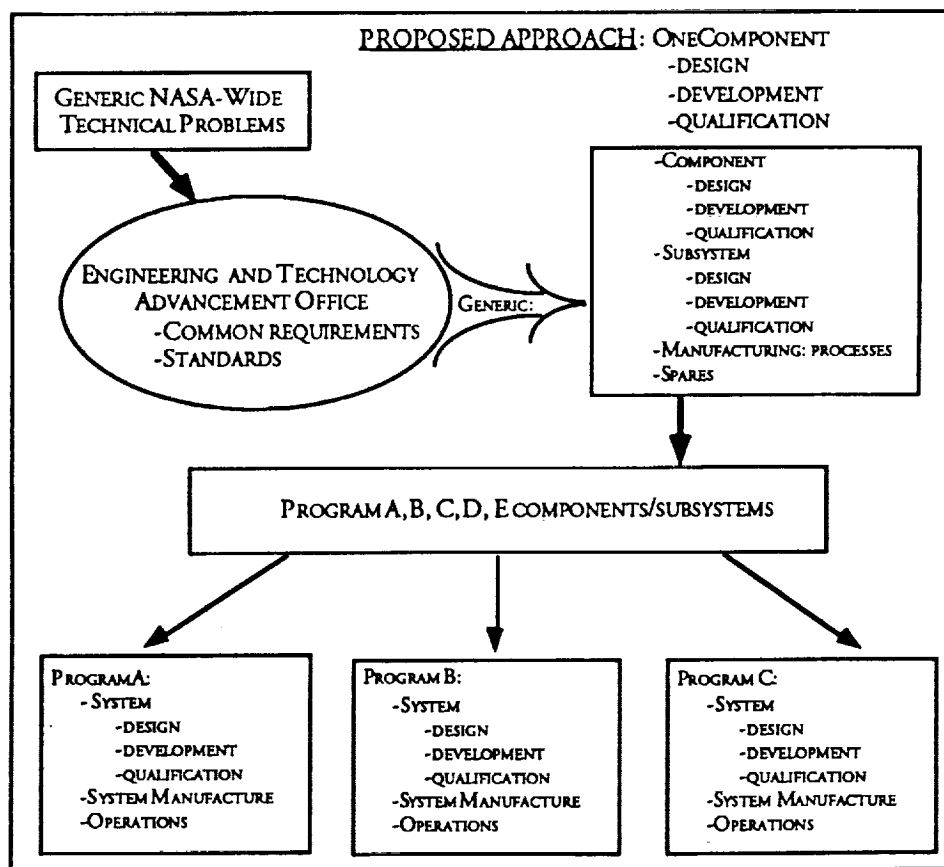


Fig. 7. Proposed approach for program development.



A true NASA-wide Standard approach has never been fully implemented. It can and should be done. This document presents an integrated systems management approach, using NASA-wide Standards which have a high probability of being successful. The key to the successful accomplishment of lower cost programs is to streamline the NASA system to provide the proper management organization which will serve as the institutional tool to implement applied technology. This will be a NASA organization, one which provides a service-oriented, applied engineering office to focus on the identification and resolution of common technical issues across NASA. Technical problems and cost increases will continue unnecessarily to the detriment of all NASA programs without that focus.

### Dedicated Engineering and Technology Advancement Office:

The relationship of the ETAO with research and its customers is shown in Figure 8. The organization between these major functions is discussed and rationale for the three distinctions provided throughout the text.

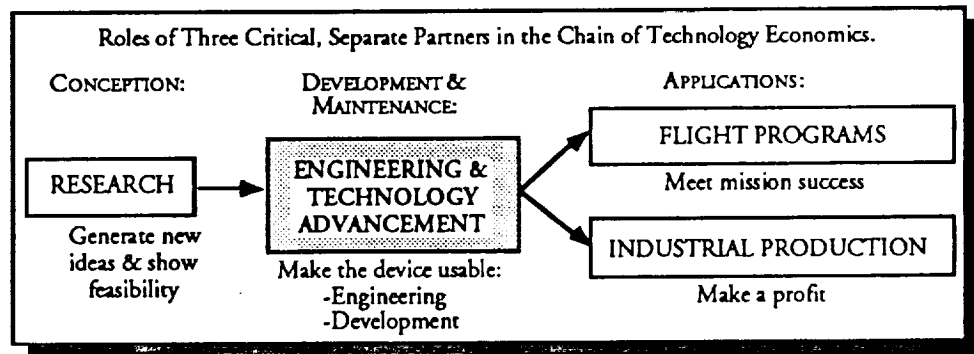


Fig. 8. Relationship of engineering and applied technology with research and customers.

The domain of engineering and applied technology is compared with that of research in Fig. 9.

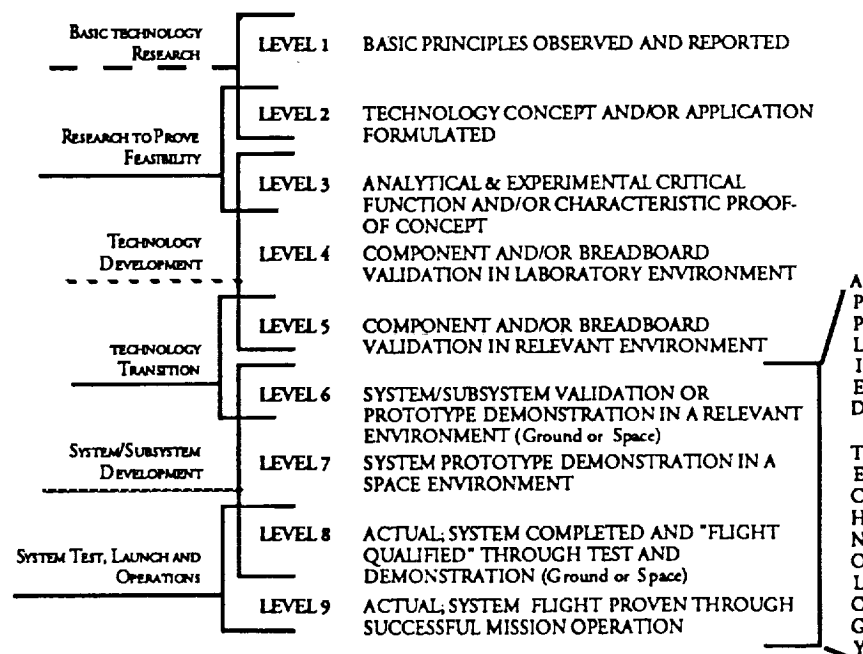


Fig. 9. Domain of engineering and applied technology.

Let us now proceed with a discussion on how the operation of an Engineering and Technology Advancement Office can be implemented.

General office functions are presented in Fig. 10 below.

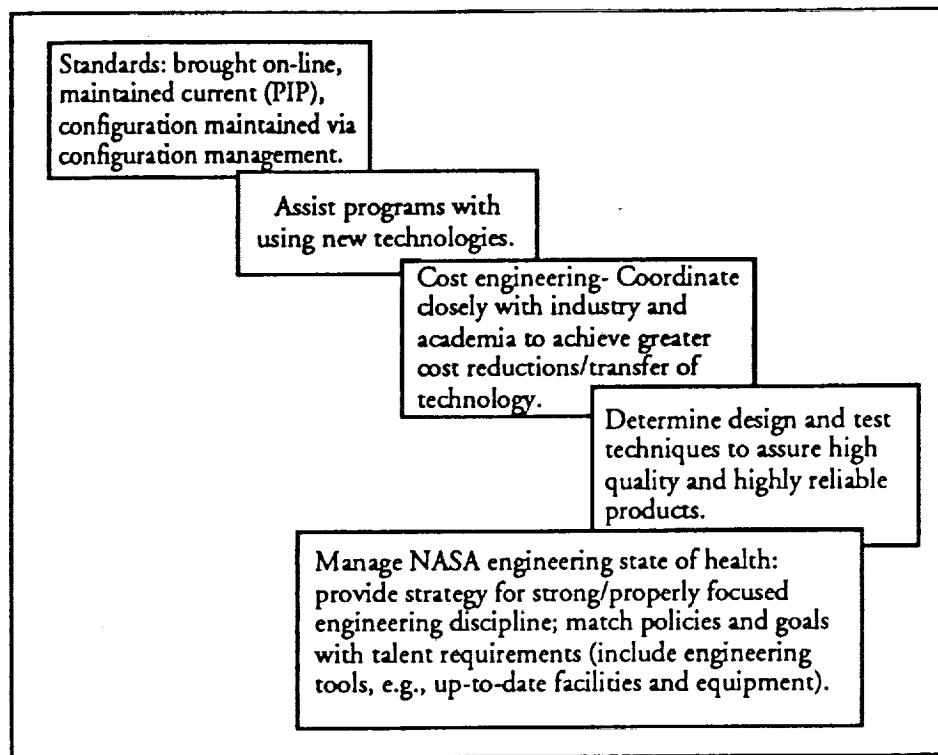


Fig. 10. General ETAO functions.

The hardware elements, i.e., the components and subsystems, which can serve as candidates for incorporation into this program are listed in "12.0 List of Candidate Items for Standards." That is a top level list. There are many functions and other specialized components that are not included, such the establishment of lessons learned data bases, modeling of processes, sensors, many individual mechanical and electrical parts, etc. A configuration management (CM) system is suggested similar to that of NASA's flight programs, one using controlled designs, change control, manufacturing process control, and acceptance testing. Product Improvement Programs are important to standards in order to avoid technological stagnation, but redesigns must be carefully tested and controlled.

Assistance to programs is provided by several strategies. These include briefings and dual use of engineering talent to serve on this program and on Agency flight programs. Cost engineering is a concept to place cost trades on change benefits: cost versus total system gain. Design and test techniques are key to establish better the intended quality and performance expectations on NASA's hardware, whether Standard or not. The management of the NASA engineering discipline is included to provide an overview of the state-of-health of engineering in NASA and to be in a position to take corrective measures as required. At the present time this is performed by centers independently. The effort here is to integrate an entire Agency engineering focus. It serves the same role for NASA engineering as the other three (formerly) program offices had served their disciplines: research (Code R), science (Code S), and space/launch vehicles/human exploration (Code M).

First, consider current-use system components. The flow of current technology into programs is depicted in Fig. 11 and discussed below:

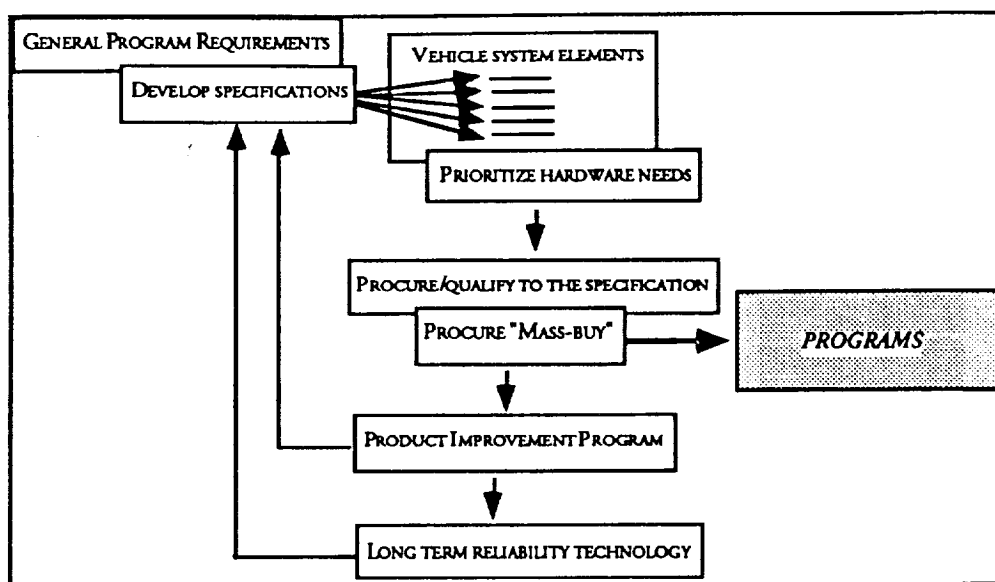


Fig. 11. Flow of current technology into programs.

1. Current-Use System Components: These are the steps which describe suggested managerial activities necessary to accomplish the program objectives for current-use system components:

- a. Define a NASA-wide set of program requirements.

Decide which programs are likely to be implemented over the near-term – the next 5 to 10 years, and the far term – 15 to 25 years, perhaps longer. The anticipation is that we will find that, in the not too distant future, space flight missions may require very long flight duration (e.g., 50 to 100 years) to conduct solar system science mission and beyond. Voyager, having been launched in 1977, is one early example of this type of long mission thinking. The Cassini mission is planned for 15-20 years – a more recent example. Space Station Freedom has a 30-year life desired. The trend toward long duration missions is clear. For planetary missions and beyond, we lack the propulsion systems to do better. Such mission durations are appropriate for today's technology planning in order to be ready when needed for use.

Working with all Headquarters program organizations, the Engineering and Technology Advancement Office will establish program priorities. The prioritized list is expected to stress long lead time items and technology that can be considered for conversion into program use at a "high risk" level.

- b. Define a very detailed NASA-wide set of specification requirements.

A range of component and subsystem specifications are developed for the programs' requirements (step a.). Then we determine candidates for common-use, the performance expected, operational environments, life expectancy, etc. For examples, it is clear that the following subsystem and components will continue to be needed: power, computers, data acquisition, data transmission, data storage, flight control, guidance, attitude control, propulsion, pyrotechnics, environmental controls, optics, fiber optic sensor components/subsystems, vehicle

monitoring systems, electrical/mechanical parts, sensor systems such as laser optic systems, etc. Refer to section 12. In this program we do not provide Standard platforms, but allow the system designer the option for designing platform(s) using Standard components and subsystems to permit specialized mission objectives to be accomplished.

- c. Prioritize to develop the most needed Standards first, i.e., those which exhibit important performance characteristics, are mission critical, are time critical, offer significant cost or safety advantages, etc., and then we quickly to qualify for use.

This is the major first step in the process of making components and subsystems available for programs to use as Standards.

- d. Submit RFP's, industry-wide, for fabrication processes such that the qualification status and manufacturing processes are maintained.

Include hardware shelf life as part of the qualification process using the specifications in Step b and the priorities established in Step c. Process control is critical, particularly where test data requires a long time, such as years, or where good test techniques are not available or are too costly or where performance less than perfection cannot be tolerated. Those are trades which the Engineering and Technology Advancement Office will have to decide. Commercial hardware and software may be acceptable where mission performance specifications are demonstrated to be met.

- e. From this point on perform configuration management for the program – i.e., rigorously control the process.

This step is essential for critical hardware, particularly where testing cannot provide quick answers and where control of processes is important to NASA's interest. An understanding of all process and operational performance variables is never complete but is only a matter of degree. The most cost-effective approach is to maintain that which has been demonstrated to work. Do, however, allow other manufacturers the opportunity to demonstrate that they have a better design or improved manufacturing process. Give them the opportunity to demonstrate that they have a cheaper, qualified product. Second sources may become important to assure lower costs, an ETAO determination.

- f. Place large purchase orders for use by programs; the economic power of "mass buy" will reduce unit costs.

Clearly, care will have to be exercised to match program needs with purchases. It will be important to reflect on the volatility of the technology. Mechanical hardware is more "mature" by being less susceptible to major changes than electronic hardware. Purchase the Standards per Steps c and d. Procurement of the Standards is funded by the Engineering and Technology Advancement Office as one of the budget line items. Two funding source options are available: (1) fund directly from an Engineering and Technology Advancement Office dedicated budget with hardware being supplied directly to programs or (2) require programs to reimburse the Engineering and Technology Advancement Office.

Programs will design the flight and ground systems to the capabilities of the available Standards. Design compromises are not expected to be a deleterious consequence since the designer knows precisely what equipment and performance capabilities are available and can design to limits established by the Standards.

- g. The above procurements, Steps e and f, are primarily relevant to components, but equally important are the subsystem considerations.

The very best components will fail in a poorly designed system. For example, a reliable power supply system requires not only good electrochemical cells but their proper operational use as well (includes operational software as well). The use of "Standardized Subsystems" will have to be examined on a technology-by-technology basis, but the concept of Standard Subsystems is as valid as the concept of Standard components.

- h. Where shelf life is proven, buy and store a large quantity based upon mission projections.

This is logistics, a new role for NASA, and one not expected to be implemented without an Engineering and Technology Advancement Office. This is where working with other government organizations and the using industry can provide financial leverage. The ready supply of hardware off-the-shelf acts as a spares reserve. This is cheaper because now a single supply of spares exists, as opposed to each NASA program purchasing its own separate set of spares. Programs will no longer be required to purchase spares where Standards are available off-the-shelf.

Because a single, poorly designed and/or manufactured part can have an adverse effect on more than one program, design understanding and process control are fundamental, essential principles.

- i. Establish one center with the responsibility for any given technology.

This avoids relearning on the part of each center and prevents a need for the duplication of facilities, thereby reducing costs. The responsible center serves as the repository of experience and maintains the data base. Other centers use the personnel from that center for the needed program expertise/training. A new level of inter-center cooperation is achieved as a consequence.

- j. Maintain the pedigree.

This is a very important new role for NASA and not likely to be implemented without an Engineering and Technology Advancement Office. An automated, comprehensive data base of performance and operational experience is maintained and is accessible by all centers. The ETAO Product Improvement Program is a part of this objective.

- k. Assist programs with the utilization of new, useful technologies.

NASA has been very conservative in the past in adopting the latest technologies into the agency's programs. That is not without good reason – program managers are not paid to take risks. In fact, the major emphasis in NASA is to control risks to the maximum extent, even to the detriment of cost and schedule impacts. Nor for that matter, should they be required to take risks with new technology because those risks are unnecessary under the implementation of the ETAO. Control of risks is currently considered important in order to maintain a mission success posture within budget and schedule. New components comprise an element of risk and, therefore, are typically excluded except where essential. The objective which this office will accomplish is a reduction of that level of risk to one of acceptability.

- l. Coordinate closely with industry and academia to achieve greater cost reductions.

At the present time our program hardware-software requirements are not defined, at least not very far out. Industry is, consequently, not in a strong position to respond with hardware and software to meet NASA's needs; nor, similarly, can academia respond by assisting NASA with advancements in research, engineering, and applied technology and in producing students with the professional skills and the mix and quantities that will be necessary. Right now this is very much a guessing game on the part of both rather than a planning activity. By getting our engineering and applied technology discipline in order, we will be assisting in mutually serving goals. Both will be ready to support our needs in a timely and organized manner. Companies will have guidance on the optimal use of IR&D funds.

One approach to accomplish step (1.) (Charter section C. - number 15) is to establish focused high-level boards to provide a peer review process:

1.) Industry related:

| NATIONAL COMMISSION ON APPLIED AEROSPACE TECHNICAL REQUIREMENTS AND ISSUES  |
|---|
| <ul style="list-style-type: none"><li>- MANPOWER AND TRAINING NEEDS</li><li>- TECHNICAL: DEVELOPMENTS/PROJECTIONS/DEFICIENCIES</li><li>- TECHNICAL: TRANSFER MECHANISMS</li></ul> |

2.) Academia related:

| NASA/ACADEMIA CONSORTIUM FOR ENGINEERING AND APPLIED AEROSPACE TECHNOLOGY  |
|--|
| <ul style="list-style-type: none"><li>- DEFINE DEVELOPMENTAL NEEDS/RESOURCE REQUIREMENTS</li><li>- DETERMINE ENGINEERING REQUIREMENTS/NEEDS</li><li>- PROVIDE MECHANISM FOR TRAINING FOR "ENGINEERING BY COST AND QUALITY" AND "ENGINEERING MARKETING"</li></ul> |

3.) Program definition and planning related:

| NASA ENGINEERING AND TECHNOLOGY ADVISORY BOARD  |
|---|
| <ul style="list-style-type: none"><li>- ALL PROGRAM OFFICES: DEFINE STANDARD DEVELOPMENTAL NEEDS</li><li>- PROGRAM MANAGERS: FROM COMPLETED PROGRAMS - DETERMINE ISSUES THAT NEED TO BE ADDRESSED</li><li>- PROGRAM MANAGERS: FROM CURRENT PROGRAMS - ESTABLISH NEAR-TERM REQUIREMENTS</li><li>- PROGRAM MANAGERS: ADVANCED PROGRAMS - ESTABLISH PRIORITIES</li><li>- RESEARCH MANAGERS: RECOMMEND CANDIDATE TECHNOLOGIES FOR CONSIDERATION BY ETAO</li></ul> |

"High level" boards have advantages as well as disadvantages. A concern exists in that details may be lost in strictly adhering to high-level boards. The perspective of persons close to problems is a

resource that must be accommodated into the ETAO via a "Low-level" Engineering Staff Board. The "Engineering Board" has the additional benefits of making the engineer aware that there is direct participation at the engineering level; and further, it provides building block experience.

| NASA ENGINEERING STAFF BOARD  |
|---|
| <ul style="list-style-type: none"> <li>– PROVIDE PROGRAM RECOMMENDATIONS</li> <li>– PRESENT PROBLEM AREAS IN NEED OF RESOLUTION</li> <li>– ADVISE ON ENGINEERING AND FACILITY/"TOOLS" NEEDS</li> <li>– CONDUCT SPECIAL AD-HOC INVESTIGATIONS AND MAKE RECOMMENDATIONS</li> <li>– REVIEW POLICY, CHANGES, AND DIRECTIVE RECOMMENDATIONS</li> </ul> |

As a sub-review activity to the Engineering Staff Board, there will be intercenter technical steering committees for specialists to make inputs. This provides a new management approach.

Now let us now address what is referred to as "research-mature" hardware but which has not yet been demonstrated in the intended application:

2. Research Mature Hardware: When the feasibility of research-mature hardware has been achieved but the hardware has yet not been flown, the steps are similar to item 1 above. Our objective herein is to make the latest technology, which is considered to be research mature, available to programs without incurring a high degree of programmatic risk (Fig. 12).

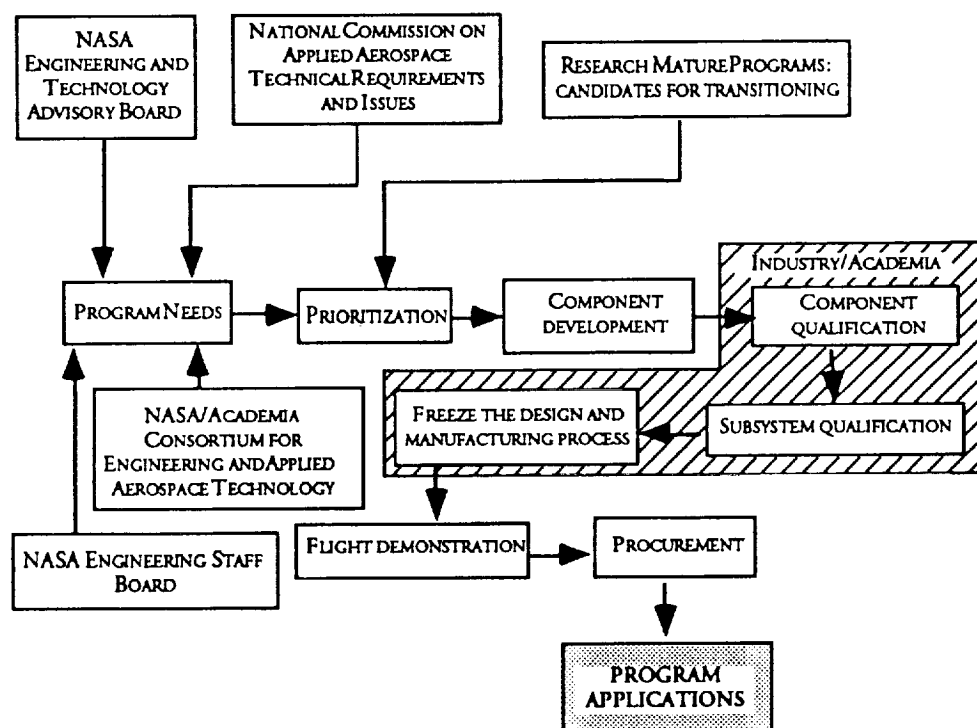


Fig. 12. Engineering and Technology Program flow to program application.

That is:

- Establish in this office a management system for NASA to provide for the incorporation of research-demonstrated hardware into the flight phase, including enhanced understanding of its critical manufacturing process parameters.

- b. Repeat Steps a. through j. in "I. Current-Use System Components" above using Step a. above to determine the priority for bringing new Standards on-line.

3. Software:

For Standard software modules, develop common use interfaces between the Standard hardware and the software required to operate subsystems and components. Standard operational systems are formed by the integration of Standard software with Standard operational hardware. Just as we make common use of hardware technology, so we employ common use of software technology.

Commercial systems are available and can do the job thereby saving NASA hundreds of millions, if not billions of dollars, over the next decade. The new office will conduct market surveys and analyses to determine potential cost savings and thus accomplish an optimal direction in which to proceed with common use software. The market technology is expected to have been widely tested, and we can leverage that wide-spread use. Implementation of the software program approach will be an early office function.



## 7.0 ANALOGY

The approach proposed herein is considered analogous to the relationship of the Program Manager with NASA's Programs, one with which we are all familiar. In the context of this proposal we view the Administrator as the Program Manager of the United States' civilian Aeronautical/Space Research Program. We have reached program maturity in many technical areas over our 35-year history. Using this perspective, we note that all programs eventually "freeze the design and the manufacturing process" after a degree of developmental maturity has been reached. NASA is a "mature" program in many senses. No longer do we lack an understanding of the environments which we needed to establish 35 years ago. We have done that. We understand the job which has to be done better now, having 35 years of experience. Many of the programmatic steps performed in a rapidly evolving technical world are known. The basic development phase of the program has been performed.

The thrust of this proposal is no different, and the rationale for using a frozen design, i.e., a Standard, is equally valid, i.e., to reduce program costs and to maintain system performance in order to assure mission success. Standard design procedures, environments, and test techniques are needed to bring programs under cost control using CM as an Agency-wide tool.

Engineering and Technology Program under the ETAO will integrate all applied technologies to consolidate commonalties rather than to permit costly divergence from the program-by-program approach that we have been using throughout the Agency's history. The technology consolidation is a fundamental objective. While individual programs may internally optimize, the overall effect on the Agency's budget is considered to be more costly when we look upon NASA in a total systems engineering sense.

## 8.0 ANALYSIS OF PROBLEMS, HISTORICAL ISSUES AND RESOLUTION, BENEFITS

What problems are we trying to solve? What are the underlying issues that cause the problems? How can these best be resolved? What are the gains anticipated? These are the topics that we must deal with to understand the proposal content.

### 8.1 ANALYSIS OF PROBLEMS;

The problems which we seek to fix are simply viewed as program adversities which are interrelated:

| PROGRAM ADVERSARIES  |
|--|
| <ul style="list-style-type: none"><li>- OVERRUNS</li><li>- FAILURES TO MEET MISSION PERFORMANCE REQUIREMENTS</li><li>- HIGH TOTAL PROGRAM COSTS (REGARDLESS OF OVERRUNS)</li><li>- ACCIDENTS AND ADVERSE ENVIRONMENTAL IMPACTS</li><li>- LENGTHY PROGRAM DEVELOPMENT</li></ul> |

#### Program Development Problems:

The need to improve upon our management system to better control overruns is well illustrated by a recent 900% cost overrun article on the front page of a national newspaper.<sup>3</sup> Another more recent article further underscores the need for responsible financial action.<sup>4</sup> In that article, and another,<sup>5</sup> a \$1B to \$500M on the Space Station Freedom overrun is reported, the subject for much follow-up debate.

Obviously, there is the real concern that public support for the space program will dwindle if not corrected. Thus, the importance of taking positive steps as proposed herein to get costs and mission reliability under better control, cannot be overemphasized. The probability of NASA being in a strong position to continue programs is enhanced with positive results on cost controls. On the front page of the same newspaper was another article, written by the same author, presenting results from the Hubble Space Telescope on the potential discovery of dark matter.<sup>6</sup> A third article written by the same author presents important results relating to basic, new data concerning climatology phenomenon which may help in understanding the forces behind the weather.<sup>7</sup>

The contrast of these two types of articles is such that they clearly illustrate a public perception of NASA about which we must be keenly aware. We lose credibility, and overruns of this nature deprive the Agency of meeting its full potential in accomplishing its goals. It is difficult to initiate new starts with a tarnished public image. There is the real hazard that "good" data presented to the public may not be sufficient to overcome the "tarnished" image data. To a large degree, we determine our fate: Get costs under control as discussed herein!

Consider the 900% overrun. The GAO stated that NASA incurred a 900% overrun with the new Shuttle toilet. While 900% overruns are not typical, overruns nevertheless are and have been widely experienced, and a substantially new method for cost overrun protection is essential to

advance the goals of the Agency. Overruns deprive NASA of the advancement of space science and prevent expansion of programs. A noticeable number of smaller overruns, or few large ones, creates a management credibility situation placing NASA in the wrong light and consequently places all of our programs in serious jeopardy.<sup>8</sup> Our customer is the United States public; and what they think is clearly based upon what they read, principally from newspaper articles. Issues like overruns and failures are topics which we clearly must address better than we have in the past in order to regain public confidence.

#### Why do we encounter overruns?

The key budget stresses on Agency planning and resources, as based upon this proposer's experience, are presented and discussed below:

1. schedule delays due to underestimating of technical difficulties (or over-optimism)
2. redesign and retest due to qualification test failures (changes)
3. low-balling of programs
4. lack of technical understanding
5. failure to take advantage of advanced technology
6. spares
7. failures/accidents
8. others.

The first rationale is interrelated with #2 and #4. A study was made on a particular technology, pyrotechnics, to determine the rationale for problems that had been experienced both in NASA and in the DoD over a 28-year span. The results showed that lack of understanding was the most significant contributor.<sup>9</sup> With regard to item (8.) above, we consider factors typically beyond our control. For example, in situations where programs had a good pre-design study effort to scope the program, and program management is arbitrarily told to cut costs and/or stretch out the program, there is little that engineering and applied technology can do to improve the situation. Another budget stress is the lack of timely support of other equipment required for a program, such as a delay in a launch vehicle availability, particularly Space Shuttle launches.

Clearly, those are factors that an ETAO will not be able to directly impact. Indirectly, however, the office can be of value. An excellent record of meeting costs will psychologically improve the situation such that high credibility will be the expected consequence, and there will less tendency to arbitrarily adjust program budgets downward. Those 8 stresses are targets for the ETAO to resolve. Note that contractual program overruns are due in large part to the first four factors.

Let us examine another source for overrun criteria, the GAO and NASA testimony as reported in the *Washington Post*.<sup>3</sup> The rationale for the overruns and testimony source reported were:

1. unneeded changes (GAO's statement)
2. acceptance of contractor recommended improvements (NASA's statement)
3. inadequate specifications existed at the start of the program (NASA's statement)
4. would have handled it differently (NASA's statement)
5. unclear instructions (GAO's statement)
6. misunderstandings (GAO's statement)
7. one company (NASA's statement)
8. difficult job (NASA's statement).

As a third source of program overrun analysis, consider the GAO report released in December 1992.<sup>10</sup> The report responded to the House Chairman for the "Subcommittee on Investigations and Oversight, Committee on Science, Space, and Technology." The GAO reviewed 29 major programs (>\$200M) from over the past 15 years.

"Almost all of the 29 programs we reviewed required substantially more funding than the initial estimates provided to Congress. ... Changes in estimates ranged from a 44-per cent decrease to a 426-percent increase over the initial estimates. The median change was a 77-percent increase." (p. 1)

These estimates were conservative because they included the budget reserves which ranged from 10 to 35 percent of a program's development budget and because the GAO used the highest program estimates whenever range data were presented.

"Estimates for nearly three-quarters of the programs increased by more than 50 percent, and one-third increased by more than 100 percent. ... Of the twelve programs that were launched, current cost estimates ranged from 14 percent under the initial estimate to 426 percent over, with a median increase of 79 percent."

Discussions with program staff knowledgeable of those programs have brought out the point that the GAO analysis is based upon program start and stop without making allowances for increases in scope after start nor events beyond the control of the program office, most notably, the Challenger accident. All of those factors are wrapped into the total overall program growth which is shown in the 79% growth number. The "real" overrun is not as great. Whatever the value, if possible to reduce overruns to 0%, then NASA would be in a position to increase the number of new programs without any increase in budget! Assume, for example, that the "real" number is 79%. Then NASA would be in the enviable position of being able to nearly double its programs without any growth in the budget. Such is the power of overrun avoidance.

Some programs are completed on cost.

It is, thus, informative to first examine those factors which the GAO report attributed (per NASA program official statements) to a program successfully meeting mission objectives, including budget: UARS and Endeavor (Ref. 11, p. 10). Refer to Fig. 13.

#### SUCCESS FACTORS:

| UARS Program   | Endeavor Program   |
|--|--|
| 1. <u>experienced</u> management team  | 1. contractor had prior <u>experience</u> building that particular vehicle       |
| 2. <u>extensive</u> definition studies to <u>understand</u> <u>requirements</u> and to <u>identify risks</u> | 2. <u>production</u> contract, <u>not research</u> program, reducing risk level  |
| 3. use of <u>existing design</u> to reduce development uncertainties   | 3. <u>experienced</u> management team  |
| 4. <u>stable</u> program funding   | 4. <u>processes</u> involved with producing Shuttle were well <u>established</u> |
| 5. substantial <u>reserves</u> at program start  | 5. <u>stable</u> program funding   |

Fig. 13. Success rationale: factors behind programs meeting budget.

Whether or not the mission objectives of the UARS and Endeavor are technically fulfilled at the end of the operational phase as planned, we leave to the future to determine.

This proposal includes efforts to provide for each of the above success factors, and in fact – it places emphasis upon those success factors. The one exception is that it does not provide for stable funding; but with program successes ensuing from this approach, the ETAO will set the stage for stable program funding by building up confidence with those public officials who make our resource decisions.

A review of Fig. 13 shows there are obvious common fault threads for the cause of overruns. Those faults have relevance to the rationale why this proposal provides a major step toward enhancing mission success and in allowing NASA to live up to budget commitments. The rationale why those 2 programs met with budgetary success are:

- experience,
- understanding,
- process control,
- use of existing devices,
- not research,
- identified risks.

The Engineering and Technology Advancement Office charter includes each of those success rationale as a direct office function. Another way of looking at many of the success criteria is that hardware change was not allowed. Further, there is a common thread of stable funding. Perhaps, as hypothesized earlier, there was confidence that these teams could deliver. A word of caution is appropriate in considering these criteria. Thorough definition studies will not guarantee that overruns will not be experienced, although the failure to have good pre-Phase A and Phase A studies will likely ensure overruns. Many programs have completed very thorough definition studies and still overrun: Shuttle, Space Station, and Hubble, for examples.

#### Long mission flight time – Twenty -five year+ qualification:

As we look to the future, drastic increases in space flight mission flight times will be required for the planetary missions and beyond. Economics may drive even the LEO missions to longer flight times. Missions of 25 to 30 years are now being discussed and planned. As planners look forward, they will find the need for missions to extend in duration to beyond 100 years. How do we cope with that need on a sound engineering basis when the requirement does develop?

Thus, today's problems with estimating costs and meeting mission success can reasonably expected to be magnified if proper steps are not taken.

#### Operations:

NASA's expenditure for operations is large, ~\$5.2B (Table 5.). The integration of an operations organization with program development has not traditionally been a strong point in NASA- traditionally and historically an organization devoted to research and program development. As a new thrust then, studies to determine the magnitude and technical nature of the potential for applied technology to impact operations is urgently needed.

\*\*\*\*\*

Thus, having defined a major problem area upon which we wish to focus - cost and mission assurance, we now examine prior major reviews of NASA to determine whether similar concerns were reported, whether these problems were recognized, the actions suggested, actions taken, and the results.

## 8.2 ANALYSIS OF PRIOR REVIEWS OF ISSUES AND RESOLUTIONS FORWARDED TO NASA

### Historical Perspective:

This proposal presents an active, positive approach to remedy a key issue facing the Agency: mission success within cost, schedule, and safety constraints. The cost impact due to the lack of safety is probably NASA's greatest unplanned single category cost expenditure, and the impact occurred from just two major events, viz., the Apollo 204 fire and the Challenger accident. It would not be surprising that the full cost impact of those two accidents combined may perhaps be nearly the same as all of NASA's cost overruns combined! that is the major reason to include safety in an applied technology program and one intended to reduce costs. They are synonymous.

Many of the issues and concerns raised have been somewhat universally expressed over the years as various studies have been undertaken. But a review and research into prior investigations and reports shows this proposal's solution to be somewhat unique. Many issues common to this proposal were reported to NASA. Solutions offered were broad. But no detailed, definitive action was taken to address these issues, particularly of the nature as suggested herein. The bottom line is that the issues remain: costs are overrunning and missions are not fully performing as desired.

Let us consider specifics. The solution as proposed herein originated with the proposer back as early as the Gemini Program era. At that time, significant problems were being encountered with small ablatively cooled thrust chamber assemblies (thrusters). A search of the literature showed technology being considered mature with feasibility demonstrations accomplished. The demonstrations were technically "near" to the Gemini requirements, but they were not exactly as needed. The supplier for the thrusters similarly lacked the engineering and applied technology understandings. The plan was to scale the design, but the scaling laws were unknown, ultimately leading to cost overruns, performance degradation, and schedule slippage. Also, in-flight degradation was experienced, a separate phenomenon from the development issue, but one of concern to an Engineering and Technology Program. The wishful thinking then was, an Engineering and Technology Program should be undertaken because it is so important to our operation. Subsequent to that era, many events on a very large number of NASA programs and numerous conversations with colleagues have reinforced basic concepts behind this proposal.

More recently, in the 1983-5 time frame, significant problems were appearing with "mature" technology such as batteries (and pyrotechnically initiated spacecraft separation systems). Going back to the literature and the expertise, one could find nothing of an engineering and applied technology nature to help. Research had been terminated in 1975 on the nickel-cadmium chemistry since that chemistry had been well demonstrated, and battery research moved on to improved chemistries such as the nickel-hydrogen chemistry. That is considered a valid research decision in both cases, and no omission or neglect is suggested on the part of the research program.

The omission is in the failure to recognize the importance to NASA of engineering and applied technology and to act upon it. The first NASA program of an Engineering and

Technology Program nature, one to pick up where Code R (Office of Aeronautics and Space Technology) had left off, was the NASA Aerospace Battery Systems Program (~1986). It was initiated in the Office of the Chief Engineer solely to address current battery problems to be dealt with in the course of using technology in day-to-day operations. The purpose was to provide gains in reliability, safety, and quality.

Traditionally, NASA staff envision the safety, reliability, and quality function and the managing office as one to conduct audits, define policy, and set requirements. The work emphasis is on oversight. "While an ounce of prevention is worth a pound of cure," active resolution of the problems is not the traditional approach taken, and the Battery Program was in that regard a management aberration. Hence, a managerial void has existed over the years, causing what this proposal suggests is an urgent need to remedy.

There is an identical analogy with the NASA Pyrotechnics Program except that this program lacks management support.

At this time it is instructive to review the results of prior concerns and of the reviews that have ensued.

There is a very wide range of historical resources that is called upon to better understand generic issues and their resolutions. Past reviews reflect the concerns of prior senior officials and the aggregate intelligence of the investigative personnel staffed to serve NASA in response to concerns raised. As seen below, the concerns are basically unchanged throughout the Agency's history. Figure 14 presents a listing of significant reviews conducted and reports prepared over the past 15 years. First, note the increasing frequency of reports on issues and problems, reflecting at least a continuation of problems, if not an acceleration. The first conclusion is that more needs to be done than recommended and acted upon in the past. Change is mandated.

| Year | Review/report  |
|------|--|
| 1977 | Lundin Report (NASA)                                   |
| 1981 | Hearth Review (NASA)                                   |
| 1983 | Office of Technology Assessment (Congress)             |
| 1983 | Solar System Exploration Committee (NASA)              |
| 1986 | Rogers Commission (Presidential)                       |
| 1986 | Payne Report (NASA)                                    |
| 1987 | Ride Report (NASA)                                     |
| 1987 | Space Technology ... Needs (National Research Council) |
| 1988 | Phillips Review (NASA)                                 |
| 1989 | Long-Range Program Plan (NASA)                         |
| 1990 | Augustine Commission (NASA)                            |
| 1991 | Thompson Study (NASA)                                  |
| 1992 | Stafford Report (White House)                          |
| 1992 | Management Issues (NASA Special Publications)          |
| 1992 | NASA Program Costs (GAO)                               |
| 1992 | Program Excellence Team (NASA)                         |

Fig. 14. Major reviews of NASA.

While it is difficult to extract fully the entire content of the above reviews, we can point out key issues raised and resolutions that were presented in the light of the focus of this proposal. The reader is referred to those reports for further information. References are provided.

#### LUNDIN REPORT (1977)

One of the earlier reports of an Agency review was written in 1977: "NASA's Management of Its Research and Technology – A Study of the Process –."<sup>11</sup> Written by Dr. Lundin using a team of NASA civil servants, in response to the Associate Administrator's request of November 9, 1976 to review the Agency's SRT program, the purpose of the study was "to improve the effectiveness of [NASA's research and technology] program, the efficiency of its operations, and to increase the opportunities for innovation and creativity."

At this point in time, some 16 years later, we are still trying to accomplish the same goals. No dedicated engineering and applied technology program was implemented as a result of that review.

Much of the report deals with the RTOP system for managing the conduct of research. The team considered the creation of a "Research Czar" to consolidate all programs for achieving proper balance, identify gaps, direct the program to meet Agency goals and objectives (pp 25-26). The suggestion forwarded was to strengthen the Associate Administrator through the addition of a dedicated deputy or assistant whose function was to overview all Agency R&T programs. A second, or related, problem was then discussed – the usefulness of the space R&T program to the rest of the Agency. (p 27) (The health of the aeronautics R&T was considered sound.) The transfer of space technology to those who could use it was reported to be "weak." Two options were considered: 1.) bring all R&T within NASA into Code R and 2.) divest Code R of all space R&T and distribute the work out to the other two program offices.

The option in this proposal, the creation of an Engineering and Technology Advancement Office, was not considered. No change was recommended beyond that of the addition of the assistant administrator. The first finding and recommendation was that "NASA has not produced a sufficiently clear and realistic set of goals and objectives to permit sound R&T program planning. Recent agency efforts to strengthen its long-range planning are therefore commended. An additional problem in planning space technology is getting more of OAST's technology used in future space flight programs." The team only recommended a small number of "major foci" be selected to provide guidance to OAST and the Field Centers. (p28) Note that this is still an objective.

#### HEARTH REVIEW (1981)

The next major senior review noted was conducted by Dr. Hearth in 1981. The study was requested by the Deputy Administrator, October 1980, the purpose being:

- "(1) To assess project management in NASA with emphasis on identifying generic reasons that aggravate cost and schedule growth of NASA projects.
- "(2) To recommend appropriate NASA actions to deal with the generic reasons."<sup>12</sup>

All projects, except the Shuttle, and all program management aspects were established as the scope of the review. The purpose was "to identify generic factors, and was not to identify the cost management of any particular project." The team comprised experienced project and program



managers within NASA. The conclusions and recommendations are reported (in part) as follows (p4):

"Conclusion 1:

The following have been significant contributions to cost and schedule growth of several NASA projects:

- "a) Technical complexity...
- "b) Inadequate definition...
  - "• Limited advanced technology development and inadequate definition of the technical, cost, and schedule requirements for the project to be implemented. Current NASA policy does not require pre-project Analysis and Definition (Phases A and B).
  - "• Over-optimism, in terms of the cost and schedule requirements for new projects, resulting from NASA's internal project advocacy process during the budget cycle.
  - "• Inadequate evaluation of the project's technical complexity and risks leading to either insufficient or inadequate reserves (fiscal, schedule, and technical)."
- "c) Low bidder selection process.... "This is recognized by industry and can have an adverse effect on the project's performance when artificially-low bids are accepted by NASA and used to rationalize low completion costs and annual funding requirements." [Referred in this proposal as "low-balling"]
- "d) Poor tracking ...."

"Conclusion 2:

The following have been significant contributors to good cost and schedule growth of several NASA projects:

- "b) Adequate definition of the project to be implemented ..."

"Conclusion 6:

Some NASA space projects have experienced cost growth in the development and implementation of their ground segments and the integration of the ground and space segments. This has been due to lack of understanding of the overall design complexity and the maturity of the overall project definition prior to implementation. This is particularly evident in high data volume projects."

"Conclusion 8:

A project will experience increased technical, schedule, and cost risk when it is dependent on the parallel development of critical supporting project systems that are outside of the Project Manager's authority."

The recommendations that followed were of a policy nature. One (Recommendation 2. e) was to require a formal, approved project plan before implementation funds are provided. A "risk assessment and identification of critical technologies" was recommendation 5, the third bullet. Many management controls were suggested, but no means for providing engineering tools were suggested. One important fact to note was that the review team did not suggest managerial

distinction between research and applied technology but stressed program planning. The problem, however, was clearly not solved. Control by a single focused office for engineering and technology was not suggested. Instead, it was to keep the two functions - research and the application thereof - unified under a single management control.

#### OFFICE OF TECHNOLOGY ASSESSMENT (1983)

The Congressional Office of Technology Assessment expressed the concern of the cost issue in a report in 1983:

"However else the publicly funded space activities of the United States might be described, they certainly would have to be characterized as being very, very costly. Today, the kind and number of space activities is no longer hindered by ignorance of the physical characteristics of the Earth's domain, by concern about the reliable in-space lifetime of well engineered and tested equipment, or by fear that men and women going into and remaining in space for as long as weeks at a time would be harmed. The unit cost of these activities is the greatest inhibition to our development and use of space. If these costs were lowered by 10 to 1000 times, many individuals and organizations would be attracted to doing things in and concerning space that today are not seriously considered or even thought of.

"Consequently, if space is ever to be widely used, a fundamental thrust must be to reduce these unit costs sharply and across the board--and particularly the cost of space transportation."<sup>13</sup>

The report notes on page 207, Appendix D,

"...extensive technological development does not appear to be necessary to obtain its necessary elements. Elements based on current technology would be less expensive to produce, with some exceptions would appear to have reasonable long-term operation and maintenance costs, would permit later improvements, would not require as extensive a management effort, and would cost the taxpayer less."

Note here that in 1983 the space program is being defined as "mature." Also, the rudiments of common use hardware is indicated: "Elements based on current technology would be less expensive..."

Here we see further acceptance of the standards concept as being a good means to control costs, although direct reference is not made to Standards. Unfortunately, we also see a stagnated technology utilization policy as a means to control costs, one that will eventually result in lagging technical capabilities.

#### SOLAR SYSTEM EXPLORATION COMMITTEE (1983)

Various program offices conducted their investigations into the means to improve programs for the greatest return. In 1983 the Solar System Exploration Committee of the NASA Advisory Council issued a report on "Planetary Exploration Through Year 2000."<sup>14</sup> The committee, comprising a wide cross of expertise - NASA, industry, other government, academia - addressed primarily missions but did not give consideration to programatics. On page 71 the report states that:

"To maintain the tightest possible control over costs, the missions of the Core program *should impose no requirement for enabling technologies* (for example, new upper stages, low thrust propulsion systems, mobile lander systems, intact sample return capability). In addition, Core program missions *must be subject to highly disciplined management*. Specifically, the recommendations contained in the Hearsh Report should be followed."

On page 82, for lowering costs, the committee suggests:

"1. Maximize hardware and software inheritance

- "• Use available spare hardware in near term
- "• Use Earth-orbital derivative spacecraft for inner solar system exploration
- "• Develop simple modular spacecraft ...

"3. Minimize changes after original mission definition.

- "• Forego missions where technology developments are of an enabling nature"

This committee shows a strong preference for standards but ignores the longer term need for transitioning technology.

#### ROGERS COMMISSION (1986)

Appointed in the aftermath of the Challenger failure, the Rogers Commission directed its attention to the cause of the Shuttle failure and the prevention of recurrence.<sup>15</sup> A series of recommendations were made to fix the solid rocket motor's design flaw and the flaws in the management system that permitted the failure to occur. (pp. 198-201)

Underlying reasons why the problems were allowed to occur in the first place was not a subject of the report.

Engineering and applied technology were not considerations given to avoid safety problems, nor were control of costs and prevention of program overruns considerations. Instead, the commission primarily reverted to the traditional role of safety, reliability, and quality, i.e., to inspect it into the program. Indirectly, one may infer that the Commission did place some importance on engineering and applied technology, although not identified as such. The discussion on "Other Safety Considerations," (pp. 178-195) shows benefit to safety resulting from the application of technology enhancements.

#### PAYNE REPORT (1986)

A bold agenda to examine the advancement of the space program into the 21<sup>st</sup> century was developed by a presidential appointed commission and from a charge by Congress.<sup>16</sup> The large portion of the report dealt with the examination of missions which extended well into the next century and was not devoted to addressing or resolving current problems. NASA responded to a 1984 Presidential directive to press forward with the commercialization of space and urged all involved government agencies to cooperate with the private sector in removing perceived barriers by establishing the Office of Commercial Programs. The Commission recommended the start of major programs like the Aero-space plane and the Space Station.

## RIDE REPORT (1987)

This report<sup>17</sup> responded to the Administrator's concern over the posture and long-term direction of the U.S. civilian space program. The objective was to evaluate potential space initiatives in order to regain and retain the U.S. space leadership position. Various missions within the solar system were examined. Efforts required to pursue the initiatives were considered. "However, in the aftermath of the Challenger accident, reviews of our space program made its shortcomings starkly apparent." (p 5)

The report points out the importance for a significant, long term commitment to developing several critical technologies and to establishing the substantial transportation capabilities and orbital facilities essential to the success of the Mars initiative. The importance of reliable Earth-to-orbit transportation was discussed as a need. (p. 40) With regard to advanced technology, "The National Commission on Space observed that 'NASA is still living on the investment made [during the Apollo era], but cannot continue to do so if we are to maintain United States leadership in space.'" (p. 40) The Pathfinder Project was cited as the guiding strategy. "Both technology development and life sciences are pacing elements in human exploration." (p. 42)

This report did not address costs, reliability, and safety which are the main limiting factors in access to space.

## SPACE TECHNOLOGY TO MEET FUTURE NEEDS (1987)

To respond to NASA's request for guidance concerning technology needs if the nation decided to respond favorably to the National Commission on Space, the National Research Council was chartered to revisit a study performed in 1982 on space research. A workshop held at that time, and the results were reported that the highest priorities must be given to technologies "that promise to reduce the cost of spacecraft systems, payloads, transportation, and operation."<sup>18</sup>

Engineering and applied technology were not approaches taken to reduce the cost of spacecraft systems, payloads, transportation, and operation, but new technology research development was discussed. The report expresses concern about the low level of technology funding by NASA and the impact of the Space Station on that budget. The report points out that "No new rocket engine development has been initiated for at least 17 years." We can now make the statement that: "No new rocket engine development has been initiated for at least 23 years."

## PHILLIPS REVIEW (1988)

The next major review, "NASA Management Study Group-II, Effectiveness of the Headquarters," was conducted by Gen. S. C. Phillips in 1988.<sup>19</sup> The study, conducted by non-NASA staff, but many having had prior NASA experience, was to assess the effectiveness of NASA Headquarters: Office of the Administrator, staff, Headquarters program management, institutional management, and planning for space flight operations in order to provide recommended improvements. The study identified the need in chart "-0004, Planning," for an integration and discretion of planning of the various organizations with an agency focus. The recommendation was made to develop a plan to satisfy the four missions of the Ride report. The need for improving cost management of operations and development was presented in chart #0031 under "Space Flight Objectives." The idea of areas of technical excellence desired by

NASA at each Center was suggested in chart # 0013. The study group stated that technology development for long duration manned space flight is currently still fragmented.

Otherwise, this study was not responding to the costs issues raised and the engineering and applied technology issues. An ETAO to integrate the fragmented technology was not suggested. There was not adequate attention given to detail as to how to prevent fragmentation.

#### 1989 LONG-RANGE PROGRAM PLAN (1989)

This report<sup>20</sup> was prepared "...for agency-level planning purposes and does not represent the Administration's approval or support of any program not included in the President's budget request." (p. I-3) Under the summary for "Space Research and Technology," the policy is written that:

"The Office of Aeronautics and Space Technology conducts the Space Research and Technology program to provide advanced technology in support of continued U.S. leadership and security in space. This program provides the wellspring of innovative and fundamental research for the future space missions that will achieve the goals of the new National Space Policy. Within the program, high leverage technological concepts are brought to the level of demonstrating proof of principle. The program also acts as a seedbed for generating more highly mission-focused advanced developmental programs." (p. VII-3)

The primary goal is stated to be to "Provide enabling technologies, validated at a level suitable for user-readiness, for future national space missions." Refer to Fig. 9. The suitable level for user readiness is flight proven, but none of the 6 objectives identified initiatives to accomplish that readiness level. Once again, that level of technology readiness is appropriate for a research organization.

#### AUGUSTINE COMMISSION (1990)

A 12-member advisory committee was established in 1990 to perform a 120-day study of NASA to advise the Administrator on "overall approaches NASA management can use to implement the U.S. Space Program for the coming decades." The membership comprised a wide variety of experience from the government, university, and industry. The report notes up-front the "criticism" which "...ranges from concern over technical capability to the complexity of major space projects; from the ability to estimate and control costs to the growth of bureaucracy; and from a perceived lack of an overall space plan to an alleged institutional resistance to new ideas and change." (p 1)<sup>21</sup>

The Advisory Committee on the Future of the U.S. Space Program, which had within its membership many persons from industry, expressed in the section on "Technology Base:" the importance of NASA providing successful programs relative to technology in general.

"...Nonetheless, the consequences of neglecting the technology base are very measurable indeed, not only impacting America's competitiveness but inducing major projects to be undertaken without a sufficient technological foundation in place. When problems are subsequently encountered, these projects must be restructured, usually accompanied by an increase in cost. The result is that major pursuits, with large work forces that cannot afford to be held in abeyance, siphon money from

smaller research projects or from the technology base itself, and the whole cycle starts anew. It seems clear that our technology base, including its supporting facilities, must be revitalized and afforded priority commensurate with its importance if major new projects are to be pursued on a realistic basis in the decades ahead." (p 21)

The importance of applied technology is well described by the Committee on page 30:

"The serious technological challenge for NASA at the present time does not relate to issues of invention or creativity, but rather to the difficult sequence of taking an invention and turning it into an engineered component, testing its suitability in space; and then incorporating it into a spacecraft system. ... A prime responsibility of the NASA technological development activity must be to bridge the gap between technology concepts and application to space practice."

This study focused more closely upon the issues raised herein and comes closer to the proposed solutions than any other review. An engineering and applied technology focused office was not forwarded, however. Indirectly, the reference to "The serious technological challenge for NASA at the present time does not relate to issues of invention or creativity ..." shows that the research organization has been performing admirably in accomplishing research. NASA just needs another organization to address the practical engineering aspects of technology utilization to work the day-to-day problems.

#### STAFFORD STUDY (1991)

In 1991 the Vice President requested charting a course for the future. The emphasis was placed on future mission architecture. The role of supporting technologies was presented on page 64.<sup>22</sup> The object of the technology review was to define the technologies necessary to support the mission architecture presented early in the report. The report described the requirements and options for a mixture of "mature" technologies and those requiring research and feasibility demonstration. The issues pertaining to engineering and applied technology were not identified. There is reference to the Mars mission requiring high reliability (p. 64, A-19, A-22) The report otherwise has relatively little applicability to the issues visited herein.

#### THOMPSON STUDY (1991)

In 1991 the Deputy Administrator issued a report to the Administrator on the roles and missions and what NASA does and how.<sup>23</sup> This report suggests that strict adherence be given, for cost economy purposes, to the "Centers of Excellence" (p 2) Another cost related topic is discussed in the section on "Improving Project Management." "Cost, schedule, and performance are really the only three variables any program manager has in executing the program once started. NASA's priority has been performance (or capability). Today the taxpayer's priority is cost control. This need to be fixed."...

- Placing major emphasis before we start a program on the technology readiness and real requirements." (p 6)

This report also covers the issue of costs, readiness, and proper understanding of requirements as presented in this proposal. While the report does not suggest an ETAO, it does relate the importance of focusing management attention on specifics, i.e., it refers to "Centers of Excellence." It is in that vein that the ETAO is recommended.

## MANAGEMENT ISSUES SPECIAL PUBLICATIONS (1992)

A series of documents on issues facing program management was recently published. One program which was presented as having a sound strategy for controlling costs was the Mariner Venus/Mercury Program.<sup>24</sup> "The study teams were instructed to consider maximum use of established designs, residual hardware, and existing capabilities." (p 33) "If a function, part, or operation was determined to be needed, then the search went on to see if hardware was available from other projects, or if the process had been developed by someone else. If the part or process was not available, then there was an attempt to use available designs." (p 35)

Note here that this is really the concept of a standard being placed into operation on a one time basis, namely, for that particular program, the Mariner Venus/Mercury Program. The program management thought it to be the right way to go for cost control. That is an old, 1973 vintage, successful program.

### GAO REPORT (1992)

The GAO report, presented historical criteria for programs not meeting budget, Tables 1, 2, 3. (Ref. 25, pp 11, 12)

Table 1. Historical reviews for cost overruns.

| NASA's Project Management Study (1980)                                   | Roles and Missions Report (1991)  | Advisory Committee on the Future of the U.S. Space Program (1990)                        |
|--|---|--|
| 1. inadequate technical and/or management definition prior to commitment | 1. need for increased emphasis on technological readiness and requirements up-front | 1. unstable program funding<br>2. consensus lacking on goals<br>3. management turbulence |

Table 2. NASA's rationale for cost overruns.

| NASA Officials statements  |
|--|
| 1. underestimating technical challenges<br>2. unrealistic contractor proposals and estimates<br>3. optimistic assessments of developing new technology |

A program-by-program explanation for changes in cost is given in Table 11.1 of reference 24. for each of the 29 programs examined. Six reasons are shown and the results tabulated below for the number of programs which experienced overruns. There is interrelationship among the reasons. For example, the long delay of the Shuttle due to the Challenger accident had a direct impact on the inflation that Galileo experienced. There is a strong interrelationship between the program redesign and technical complexity. Changes creep into the overrunning programs. Avoidance of changes is essential to keep costs from diverging. ETAO addresses resolution of the major problem areas through Standards.

Table 3. GAO's analysis for cost overruns.

|  | Causes for programs experiencing cost changes |                      |                   |                     |               |                     |
|--|---|----------------------|-------------------|---------------------|---------------|---------------------|
|  | Program redesign                              | Technical complexity | Budget constraint | Inadequate estimate | Shuttle delay | Inflationary effect |
| Number of programs experiencing cause for cost increases | 15  | 16                   | 12                | 11                  | 9             | 16                  |

## PROGRAM EXCELLENCE TEAM (1992)

While the cost problem has been a nagging one for NASA as made evident from the above studies, the problem persists. In the "Policy Revision Proposals for Management of Major Development Programs & Projects briefing on December 17, 1992 (chart 2-2652-54) a major finding is that many factors drive NASA program cost and technical risk exist including: an inadequate Phase B definition, unrealistic dependence on unproven technology, and cost estimates that are often misused. An objective is presented as "Enhance agency's ability to live up to New Start cost estimate and schedules." "Ensure all program 'New starts' include the most current technology."

Analysis of reviews:

The focus of this proposal is a better directed NASA through substantial reductions in program costs and reduction of overruns and with enhancements in mission success. Freedom from accidents – safety – is implied in mission success. It is in that light we analyze the reviews of NASA.

The results desired from this proposal are to attain NASA's goals safely and within cost and schedule. The proposed approach is that those goals are accomplished by having on hand, where the technology permits, an existing set of Standard components and subsystems, including hardware and software, for programs to readily draw upon. Overruns are reduced, and the basic cost of systems is reduced for several reasons. This process takes advantage of the leveraging provided by "mass buys." Schedule delays from Standardized hardware development problems are eliminated in situations where a source of qualified flight equipment is readily available off-the-shelf. The performance of the Standard is well-defined. The failure modes are well understood and properly controlled. In cases where there is performance capability in excess of the need, the margin is higher, thereby offering increased mission reliability. Mission failures attributed to hardware failures will be substantially reduced. A typical example of a Standard approach component is illustrated in Appendix A. Costs will be significantly reduced as illustrated and discussed in the costs section. NASA becomes an up-to date consumer of its latest research products by having in place a mechanism for incorporating the latest technology into flight qualified and demonstrated hardware ready for immediate use by flight and ground programs.

The results of the analysis of reviews are summarized in Fig. 15. The reports were not necessarily intended to address the issues raised. We simply use their information as a data source to determine the consideration that might have been given to today's issues and what was the response taken. The historical review was intended to be complete. Note that a large percentage



of the major reviews addressed missions. Receiving less attention were reviews on how NASA's missions could be accomplished in an improved manner by addressing specific problems with specific solutions. The Lundin report in 1977 addressed some problems raised herein. The Augustine report was particularly relevant. Assurance with the appropriateness of the proposed solutions is gained because prior reviews attributed cost savings to the use of existing, readily available hardware. Also, there were several recommendations to use a single office to focus on a particular function – a major recommendation provided herein. Program cost is another old unresolved issue.

Note that the summary and the issues addressed were singled out of the reports in-so-far-as they were relevant to this proposal's content. Only key words are shown; to fully understand the entire report, the references cited should be consulted. Also, the intent of the report was used, not necessarily the exact terms. For example, the Mariner Venus/Mercury Program gave a strong endorsement to the use of current, existing hardware to lower costs; that is considered to be equivalent to endorsing the Standard concept since that is basically what a Standard is considered to be.

| YEAR | REVIEW/REPORT            | Focus:  | ISSUES ADDRESSED |          |                |           |            |               |             |             |                |              |                |                | BRIEF SUMMARY OF SOLUTIONS TO ISSUES    |
|------|--------------------------|---------|------------------|----------|----------------|-----------|------------|---------------|-------------|-------------|----------------|--------------|----------------|----------------|---|
|      |                          |         | 1. OVERBUDGETS   | 2. COSTS | 3. RELIABILITY | 4. SAFETY | 5. APPLIED | 6. APPLICABLE | 7. TRANSFER | 8. PLANNING | 9. LOW BALLING | 10. HANDS-ON | 11. INNOVATION | 12. DEFINITION |   |
| 1977 | LUNDIN REPORT            | ISSUE   |                  |          |                |           |            | X             | X           | X           |                |              | X              |                | APPOINT DAA FOR CENTRAL OVERVIEW        |
| 1981 | HEARTH REVIEW            | ISSUE   | X                | X        |                |           | X          |               |             |             | X              |              |                | X              | APPROVED PROGRAM PLAN BEFORE START      |
| 1983 | OFFICE OF TECH. ASMT.    | ISSUE   |                  | X        |                |           | X          |               |             |             |                |              |                |                | USE CURRENT TECHNOLOGY                  |
| 1983 | SOLAR SYSTEM EXPL. COMM. | MISSION |                  | X        |                |           |            |               |             |             |                |              |                |                | USE CURRENT TECHNOLOGY + HEARTH         |
| 1986 | ROGERS COMMISSION        | ISSUE   |                  |          |                | X         |            |               |             |             |                |              |                |                | DEDICATED SAFETY OFFICE                 |
| 1986 | PAYNE REPORT             | MISSION |                  |          |                |           |            |               |             |             |                |              |                |                | START AEROSPACE PLANE & SPACE STATION   |
| 1987 | RIDE REPORT              | MISSION |                  |          | X              |           | X          |               |             | X           |                |              |                |                | LONG TERM TECHNOLOGY COMMITMENT         |
| 1987 | SPACE TECHNOLOGY... NEED | MISSION |                  | X        |                |           | X          |               |             | X           |                |              |                |                | TECHNOLOGY RESEARCH + MORE FUNDS        |
| 1988 | PHILLIPS REVIEW          | ISSUE   |                  | X        |                |           |            |               |             |             |                |              |                |                | MANAGEMENT IMPROVEMENTS                 |
| 1989 | LONG-RANGE PROGRAM PLAN  | MISSION |                  |          |                |           |            | X             | X           |             |                | X            |                |                | PROOF-OF-PRINCIPLE                      |
| 1990 | AUGUSTINE COMMISSION     | BOTH    | X                |          |                |           | X          | X             | X           |             | X              |              |                |                | ENHANCE APPLIED TECHNOLOGY              |
| 1991 | STAFFORD REPORT          | ISSUE   |                  |          | X              |           | X          |               |             |             |                |              |                |                | FUTURE MISSIONS                         |
| 1992 | THOMPSON STUDY           | ISSUE   | X                | X        |                |           |            |               |             |             |                | X            |                |                | CENTERS OF EXCELLENCE, PROG. DEFINITION |
| 1992 | MANAGEMENT ISSUES        | ISSUE   | X                |          |                |           | X          |               |             |             |                |              |                |                | AVAILABLE HARDWARE                      |
| 1992 | NASA PROGRAM COSTS       | ISSUE   | X                | X        |                |           | X          |               |             |             | X              |              |                |                | AVOID CHANGES                           |
| 1992 | PROGRAM EXCELLENCE TEAM  | ISSUE   |                  | X        |                |           | X          |               |             |             | X              |              |                |                | SUPPORTS APPLIED TECHNOLOGY             |
| 1993 | PROPOSAL                 | ISSUE   | X                | X        | X              | X         | X          | X             | X           |             | X              | X            | X              | X              | APPLIED TECHNOLOGY INCLUDE STANDARDS    |

Fig. 15. Summary of issues addressed by major reviews conducted.

Key-

1. program overruns/schedule delays beyond initial cost
2. total program costs
3. reliability
4. safety
5. applied technology needs (current and bridge the gap)
6. applicability to Agency goals needed
7. technology transfer to industry
8. strategic planning for research
8. low balling
9. hands-on experience
10. innovation needed
12. program definition/planning needed

## Engineering and Applied Technology:

The Lundin report (1977) was the first review found in the library expressing a concern of an applied technology nature. The OTA, Ride, NRC were all supporters of that concept. The strongest was the more recent, the Augustine report. The most advanced responsibility from the aspect of technology transition to flight status was that Code R should proceed just to proof-of-principle.

One of the ETAO functions proposed is to provide a means to transition technology to programs. The concern is that NASA lags in the use of new technology because of the risks involved being the first user of new technology. This is addressed by the more recent study: "Ensure all program 'New starts' include the most current technology." (re PET) This may be a road map to higher costs not only to the program but to NASA as well. Technology for the sake of technology may have the opposite effect desired. The ETAO acts to reduce risk in the transfer of technology without using programs as pathfinders, i.e., do the technical engineering homework before committing to programs.

### Use current technology (a precursor for Standards):

The OTA and SSEC reviews both strongly suggested that the use of current technology is important to effecting savings. The recommended use of current technology is considered as embellishing the Standards approach. The Management Issues document supported the use of Standards during the discussion on factors contributing the success of Mariner Venus/Mercury Program, although there was no reference to Standards per se but just that they could make use of whatever was available to achieve savings.

### Program definition:

Considerable attention has been devoted in the results of the above studies to making the conduct of good Phase A studies as key to resolving the cost/overrun problem (cf Hearth report). In other words, the objective is to assure that programs are in a state of readiness before proceeding into Phase B. Clearly being ready is important, although being ready, as discussed earlier is no guarantee that programs will be on-budget, on-schedule. The question is, "When is a program ready and what constitutes readiness?" Is not the state of hardware readiness at the time of proposed program start at least of equal value to the analytical readiness of the Phase A study quality? The issue here is analysis versus proven hardware/software readiness. The point made is that both are needed. Program offices do the analytical readiness. The ETAO performs the hardware readiness. It will assure the state of readiness of common use hardware and software and thus assist programs in being ready for Phase A analytical projects as well as for Phase B system design.

### Single office:

This proposal suggest that benefits will result by having technological focus at one single location. Several of the referenced studies reach the same conclusion.

- “• NASA management review the mission of each center to consolidate and refocus centers of excellence in currently relevant fields with minimum of overlap among centers (Recommendation 13).” (p. 48)

Consolidation into a single office was considered by Lundin but was not forwarded. The only change recommended was to add a Deputy Associate Administrator to overview all Agency

R&T programs through a consolidation into a single focused responsibility, reflecting the ideas proposed herein. The Phillips report hints at consolidation of technology being appropriate by the discussion on technology development for long duration manned space flight being still fragmented. The strongest proponent for focused responsibility was Thompson. He suggested that strict adherence be given, for cost economy purposes, to the "Centers of Excellence."

#### Hands-on experience:

Both the GAO and the Augustine reviews advocated the improved use of hands-on expertise.

#### Conclusion:

Some elements of each of the key ideas forwarded herein have been considered or suggested in some form in prior reviews. But the results desired as expressed herein were not accomplished. An ETAO and standards were hinted, but the reports did not go to that level of detail.

### 8.3 BENEFITS

The successful implementation of this proposal will assure a much higher probability of program mission success with significant cost reductions to NASA. This program provides programs with the tools necessary to perform missions with a reduction in risk and a reduction in cost as well as a significantly increased probability of meeting with mission success on schedule. By supporting this proposal, management will be placing emphasis on the achievement of Agency mission objectives rather than on building hardware for individual programs.

Emphasis is placed upon the importance of a dedicated office to address the subject of engineering and applied technology. The use of a single dedicated office is a more efficient approach, one to unify this discipline throughout NASA. The chance of meeting with success is considered to be drastically enhanced. This is one key element of the resolution to the proposal's issue. The Integrated Technology Plan states that the program takes "technology to a maturation of level 5 (refer to Fig. 9) which is characterized as component or breadboard validation in a relevant test environment (including space)."<sup>25</sup> Engineering and applied technology advances the technology to the flight proven demonstration in a system, i.e., level-9.

Consider the Challenger. One of the criticisms made by the Commission was that the Chief Engineer's Office served two functions – engineering and SR&QA. The Commission recommended that a single dedicated safety office be established to avoid dilution of the safety efforts. The report points out the hazard that can result from having offices with dual responsibilities. NASA has, until recently, maintained launch program development activities and operations work all under the same office (Code M). Since development precedes operations, operations was short changed: "According to Johnson officials, reductions in the program for a number of years, at least starting in the mid-seventies and running into the mid-eighties ..., intentional decisions were made to defer the heavy build-up of spare parts procurements in the program so that the funds could be devoted to other more pressing activities." (Ref. 15, p. 173) That point is confirmed by a key manager at Rockwell as discussed under the "Operations" section below.

The concept of common use hardware is applicable to both large and small programs. The current trend in NASA is to down-size programs as was recently implemented on the EOS program because of cost growth and concern over the large economical impact if one of the large programs failed. Yet, because of those two issues, we may well increase the cost of doing business

in space and may limit/prevent that science which is enabled by large programs. Using the advantages of shared commonalty, it is cheaper to have one large, multiple purpose program than a conglomerate set of smaller ones – provided that the large program does not fail. We need, thus, to face the engineering issues head-on and resolve any issues with engineering solutions. Observe that the Standard concept is even more applicable to NASA in a down-sized program mode; and for those spacecraft, Standards can effect very substantial economies.

Consider, for example, the case of large programs such as Apollo or the Shuttle, which were under one program manager. There were commonalties and approaches used throughout the program for reasons of economy and reliability (see Appendix A). Now in the case of several small programs replacing the large one, there will be a diverse set of managers who would have, under a large single program, been united under one program manager. There will be the tendency for each to “optimize” and hence to go their own way. Separate qualification test programs for each of the mainline programs can result. That will be unnecessarily costly by comparison if Standards were available, permitting generic, already qualified hardware, to be used.

The result of intermingling responsibilities can be illustrated by history. In the 1977 Lundin review the report stated: “An additional problem in planning space technology is getting more of OAST’s technology used in future space flight programs.” Nothing happened to cause resolution. There was no dedicated office, and for that matter, none was recommended – just a senior Deputy Associate Administrator or an Assistant Associate Administrator to provide an overview across all of the R&T work performed at the different offices in NASA.

NASA scientists, upon completion of lower energy space missions, will be compelled to look to longer flight times to accomplish missions requiring higher energy levels since the current propulsion systems are severely performance limited. This program will address the development of hardware for longer flight times to the planets in the solar system where current propulsion systems are severely performance limited. The ability of program managers to qualify components and systems for such long duration missions will range from severely limited to impossible; and consequently, high program risk will be assumed. The program development and flight times will be such that the mission will outlive any single manager. There will be a number of managers who will have had a role in sharing program success responsibility.

The Standard may be the only viable approach for the economical and reliable conduct of future missions, such as those requiring 25 years, or longer. Thus, this program provides the type of continuity needed for some future missions, as well as an office which serves to bridge the engineering and applied technology management gap.

An optimal approach to resolve the dilemma of long duration missions compatible with low risk is to make use of hardware possessing a high degree of pedigree. Pedigree is a strong feature of a properly conducted Standards program. Refer to Appendix A as an example of this benefit.

The Space Station Freedom is a current example of a long duration mission, one planned for a 30-year duration. The Space Station’s long duration problem is small in comparison with the remote planetary missions because it is at least theoretically accessible in low Earth orbit (LEO) for maintenance. The cost of the hardware, however, is another matter. For example, if common use batteries/cells had been developed, then the technology developmental costs for the power plant could have been significantly reduced. The same applies to other potential common use elements aboard the orbiting laboratory.

Much development design and development work is proposed to be accomplished by NASA engineers because hands-on experience is mandatory for survival by any organization. From hands-on experience, we become an educated buyer which is essential if we are to reduce costs in a major way. This program includes an in-house hands-on expertise. To illustrate, let us revisit the *Washington Post* article on the overruns of the Shuttle toilet since it is recent, and it shows many of the points addressed herein.

NASA has not performed R&D on the technology in which the GAO states had encountered a "900% overrun." Although there was disagreement stated in the article, the disagreement was only a matter of the degree of the overrun. If a hands-on space toilet design expertise had existed, in NASA, design faults would not have been permitted. We would not have bought the contractor-recommended changes. While Standard toilets are not necessarily proposed, this article serves to illustrate an example of a need for hands-on benefits.

Even without a provision for developing hands-on toilet experience, the Engineering and Technology Advancement Office could have provided assistance. The *Washington Post* article, NASA asserted that the contract was signed prior to completion of the specifications. In an oversight role by senior, experienced engineers as promoted by this program those difficulties could have been prevented through the service of an independent technical peer review process which would have identified the contract not to be ready for award – part of the management rationale why an overrun was experienced.

With concern about the hands-on capability of NASA's technical work force, the Administrator requested, in March 1990, the National Academy of Public Administration to study whether NASA has "contracted out too much of its technical work to remain a 'smart buyer' of technical products and services from industry." Other questions directly related to the issues raised in this proposal concerned the importance of hands-on experience and "whether the science and engineering capability has been 'stretched too thin.'"<sup>26</sup> (p. vii)

The panel, chaired by Harold Finger, stated "that the agency [needed to] take actions to rebuild its civil service in-house technical capability," and they made the following recommendations:

- "1. Prepare and issue guidance on technical functional areas to be reserved for in-house civil service performance.
- "2. Convert contracted technical functions essential to in-house capability from support contractors to in-house performance and rebuild strength in specific technical disciplines critical to agency programs and objectives. Ceiling relief should be sought if required.
- "3. Provide policy guidance to the centers to retain in-house sufficient project, experiment, advance development, and research activities to provide more hands-on technical work by civil service scientists and engineers.
- "4. Examine the project mix at each center against agency and center goals and objectives. Select those with marginal contributions and/or staffing for cancellation or transfer. Assess all projects for suitability of specific center assignments, avoiding intercenter overlap or duplication where possible.
- "5. Institute an annual position review for all technical disciplines...
- "6. Modify the agency's contractor accountability process by tightening controls...
- "7. Seek opportunities for greater delegation of resources/technical decision making authority, reducing multi-party sign-off requirements with encouragement of

reasonable risk taking, and improving lines of authority, responsibility, and accountability in the technical management organization."

The theme of those recommendations is reflected by the content of this proposal: the importance of hands-on experience, the need to increase hands-on experience, experienced buyers being necessary to cut costs, dedicated office functions, tight controls, and clear definition of responsibilities.

The value of the Engineering and Technology Advancement Office expertise is, thus, clear for a number of reasons.

### Operations:

Operations is a large consumer of NASA's resources; this office provides the opportunity to effect cost savings on future programs by addressing technology enhancements which can reduce operational costs. Technologies can decrease operations costs in a variety of ways, such as, by reducing functions, reducing maintenance, and by automating manual processes to provide more rapid mission turnaround.

In the ETAO, technology will be used to help reduce operational costs. Notice that NASA's developmental programs are designed to demonstrate the readiness of programs for flight and to reach an operational status. But we lack developmental programs for operations. Yet most of the program life cycle is frequently spent in the operational phase. A good systems engineering approach would assure that the two are properly integrated into a unified development activity and that a proper balance between the two functions is achieved.

One example of flight technology to improve ground operations is a flight control system which is powered electromagnetically (EM) (i.e., powered by motors) rather than by Auxiliary Power Units (APU's). Had such technology been made available for the Shuttle program development, the cost savings in development and operations is estimated to be in excess of \$200M.

In light of the above statement on the integration of operations with the development of flight hardware, precisely what we mean is this. The initial cost trade made by the flight vehicle development program may be in favor of an APU or the EM system. Development of the APU may well have been the cheaper option for flight use based solely upon the Orbiter program developmental costs. But when the added expense of the operational impact is studied, that trade could have very well turned out to be an incorrect conclusion. The latter situation is an example of a true systems engineering approach to technical cost analysis.

One of the key Rockwell managers for the Shuttle Program, Dale Myers, also later NASA Deputy Administrator, in a discussion on "Cost Per Flight" which was badly underestimated, had this to state about the integration of operations with development: "In retrospect, I have become convinced that some of the projected launch costs reductions could have been obtained, had the entire team concentrated on operations as strongly as they concentrated on development."<sup>27</sup> (p. 43)

The Advisory Committee on the Future of the U.S. Space Program made a similar statement in their report: "Concerns; ...Eighth, space projects tend to be very unforgiving of any form of neglect or human failing - particularly with respect to the engineering discipline. Spacecraft incorporating flaws are not readily 'recalled' to the factory for modification. It is this category of

problem that has evoked much of the criticism directed at NASA in recent years, although with new technology there are growing opportunities for systems that are 'self-healing.'"<sup>28</sup> (p. 2)

One part of the business of the Engineering and Technology Advancement Office is to assure the timely readiness of such technology. Other areas for operational enhancements is in the high reliability, mass-buy advantages. Technology can help through consolidation of facilities as greater information capabilities are developed like fiber optics and software advancements. Vehicle health monitoring, being widely touted for flight systems, may have highly efficient ground variants that will enable more operational capability using less resources, while providing a higher quality operations product. Much of the operational advantage gained from ETAO will be based upon establishing a reasonable set of technical requirements which engineering and applied technology will be able to assist.

Additional benefits are illustrated and discussed in Appendix A and the section on costs.

## 9.0 SPIN-OFFS

This program will be exciting from the technical perspective. A deeper understanding of the control of processes which are critical to devices performing while operating under a variety of operational conditions will be gained. The office focuses not upon the research of new equipment to provide new capabilities, but it directly concentrates upon making systems work reliably and at reduced costs.

This management approach to address a critical issue is intended to be a model for close government-industry-academia interactions. Improved understanding of processes are expected to benefit the United States industry by developing better defined quality control measures, hence, higher quality products. A highly organized approach to the rapid development of technologies will help the United States stay a step ahead of its international competitors, and product quality improvements will assist in maintaining that lead. The objective is to move technology quickly from the laboratory into practical applications. If NASA can demonstrate that this can be done without the typical delays that have become synonymous with the governmental process, then that feat in itself will have great value as a program by-product.

The Advisory Committee on the Future of the U.S. Space Program, which had within its membership many from industry, expressed the importance of NASA providing technology to the U.S., in general not just aerospace, in their report in the discussion under "Technology Base:"

"...Nonetheless, the consequences of neglecting the technology base are very measurable indeed, not only impacting America's competitiveness but inducing major projects to be undertaken without a sufficient technological foundation in place." (p. 21)

In the process of concentrating the application of technology to NASA missions, engineering and applied technology marketing can also be developed to extrapolate aerospace technology beyond the aerospace industry to other U. S. industries - a "dual applicability" role. The NASA Spin-off magazine identifies many products that NASA never had under consideration at the time that the project was started. That spin-off market for NASA's products can be expanded. Marketing comprises two functions: analysis of needs and the communication of capabilities. Until recent times, NASA was predominately NASA's customer. In today's reality, that is not good enough. The application and customer of NASA's technology is the United States economy as well. Indeed, the analysis of current needs is not adequate; we must get into the projection of future needs in order to be timely.

An example of the dual applicability role (aerospace/non aerospace) referred to is laser diode gyros. This new technology can provide the kind of reliability for gyros that solid state microcircuits has provided to electronic devices. NASA could readily use this technology if an Engineering and Technology Advancement Office existed. Yet mainline flight programs have refrained from its use because it has not been flight qualified and flight proven. We continue to try to get by with less than the optimum technology.

Who can blame a program manager for seeking out new technology unless absolutely mandated. Now if NASA had continued plans to continue the development the device would be ready for programs to seize for use on future programs without fear of the unknown resulting from newness. For the non-aerospace application, there is simultaneously an obvious market for the use of very reliable laser gyros in the automotive industry for navigation, provided it can be made at an affordable cost. There is tremendous market potential beyond aerospace. The



Japanese are already integrating fiber optic gyroscopes into automobiles<sup>28</sup>. Perhaps this technology will unfortunately take the same course of many other technologies which were transferred to the more aggressive foreign industries.

That example also illustrates a dual application of NASA's technology potential. The objective of the two industries, aerospace and automation, are the same, i.e., inexpensive but very reliable navigation equipment.

A number of years ago, the founder of Teledyne, George Kozmetsky, had a contract for building the mass spectrometer for Viking. He researched the industry and discovered that the mass spectrometer's specification was close to a need by every hospital in the U.S. He approached NASA with a few specification changes which he demonstrated would change the market from 2 units to 10,000 units! NASA, lacking an Engineering and Technology Advancement Office of the type proposed herein, refused!<sup>29</sup>

The use of NASA's engineering and applied technology capabilities beyond the Agency's immediate mission is, thus, clearly important.

## 10.0 DISCUSSION

As with any approach there are pros and cons. While the pros have been presented and positive steps identified to circumvent potential concerns, it is worthwhile to discuss the cons. Some concerns originated with the proposer, whereas others who reviewed the proposal contributed. The proposed program has been structured with the objective of removing threats from these issues.

1. There was a "low cost" office initiated back in the early 70's which was "unsuccessful."

Response: Reasons for the low cost office not continuing were considered to be attributed to:

1. penalties due to the use of only 1 (one) design to cover a wide range operational requirements,
2. hardware designed to environmental requirements which were too wide, resulting in a device that was overly massive and power consuming,
3. inadequate acceptance by all centers.
4. using a standard platform approach which was not a versatile tool.

Good planning will prevent the first and second problems. Multiple design sizes will remedy concerns about overly severe performance penalties. The ability to properly plan and manage will be a function of the understanding requirements, resources provided, and cooperation to address the issues. Environmental requirements on hardware for meeting launch dynamics are not much different. The number of launch vehicles is very limited. With the exception of the local planetary environments, space is pretty much a common environment. A wide range of environments is, in general, not expected to offer intolerable penalties. Variances in mission performance requirements is the greatest concern; and there the size options, based upon a good definition of requirements, should keep penalties to an acceptable minimum. For example, a study of power requirements might show that future energy storage needs could be met by 50 AH capacity batteries, but that the majority fall within 30 AH. That would indicate that two sizes would be warranted: a 50 AH cell design and a 30 AH design.

The success of the office will be a function of the leadership shown by Headquarters. That leadership will be exhibited by adequate support of resources and proper staffing. The GAO study showed that stable funding is one parameter necessary to produce a successful program. A service organization with a sellable product will comprise the best judge of program success.

Communications will be essential to prevent the second reason from becoming a critical issue. The program should sell itself, but an option is directives, effective on all new starts. Cooperation and acceptance of Standards by the centers is expected to be a function of inter-center coordination. The center engineering staff will not want to buy into something that they do not understand. In this function too, the Headquarters role will be vital. Various steering committees will be established to assure that inputs from all centers are incorporated, and the various technology programs will be jointly managed with all centers participating. In this manner, a Standard will not be identified as "the XXX center's tape recorder," etc., but instead it will be the "NASA Tape Recorder." Further, good inter-center planning is essential to understand fully the design and operational requirements that the common use elements will be designed to meet. The NASA/DoD Battery Systems Steering Committee and the NASA/DoD/DoE Pyrotechnic Systems Steering Committee, pathfinders in cooperative inter-

center engineering pursuits, have demonstrated the value of communicating and having centers working effectively together. It should be noted, too, that the steering committee members in the 2 aforementioned committees also participate in the management of the respective programs as is being proposed herein, thereby developing ownership. The membership consists of technologists who have program responsibilities on various flight programs, so a direct interchange of technical information exists between technology and programs.

The idea of a Standard is an inherent one covering much of NASA's history. Actually, in a sense, many of the recommendations noted in the SSEC recommendations, in essence, constituted a de facto recommendation for a Standard approach. In a sense, the Standard approach is used in principle as shown by the use in some programs of hardware designed for different programs.

Now that the Space Station Freedom has encountered funding problems, the redesign philosophy is to effect program economies by taking advantage of existing hardware and to make use of existing technology. This program has fallen into the same trap that others have and which others will continue without this Engineering and Technology Advancement Office. There is no better example or statement showing why this proposal's philosophy is sound and why this effort should be implemented.

A restraining force in the acceptance of any new idea is the natural human trait that abhors change. Vested interests may feel threatened by Standards. Headquarters leadership will be important in surmounting those obstacles.

## 2. Technology will change too fast to make this work.

Response: To the contrary, this program will cause new technology to be implemented faster -- in contrast to the way NASA has done business since its inception. In the near risk-free approach now expected of program managers, the implementation of new technology has been at a severe disadvantage. No program manager wants to take the risk of the unknown, so the old, less desirable technology is typically used instead. NASA, as a result, has become an organization not always using the latest technology. Programs cannot afford it. The reward to a program manager is on-time and on-cost performance -- not on incorporating new technology into the program, unless absolutely mandated. And, from the perspective of the program manager, if missions objectives are met without it, why take the risk?

Consider examples illustrating programmatic results using the current approach. The United States communications industry has been using the new nickel-hydrogen battery/cell technology in space for over a decade. NASA performed nickel-hydrogen cell research, thereby demonstrating feasibility; but advanced development, permitting immediate flight use, was never accomplished. Until the Hubble Space Telescope (HST) was launched, NASA had never used that technology in a flight program although it offered significant potential for longer life and higher performance than the current (nickel-cadmium) technology. Under the present way of doing business, the HST was launched with new technology batteries which had not completed a full life cycle qualification program. While those batteries are currently functioning properly, this technology proposal, had it been in effect, would have prevented the undesirable situation of launching flight batteries not fully demonstrated and, further, would have provided flight qualified batteries in time for flight.

As another example, consider gyros. Laser gyros, using solid state technology with the potential for changing the gyro technology in a manner similar to that which transistors and

diodes changed electronics, have lain abated in space applications due to the lack of demonstration and flight qualification. However, the technology has been in use in aircraft. There has been no flight program in NASA to flight qualify and demonstrate flight performance of a high performance - high reliability gyro which programs will require in the future. Flight programs focus on existing, proven capabilities.

Not all technologies are alike. Care must be taken to avoid over commitment in rapidly evolving technologies, most notably electronics. With those technologies, standards planning will not be extended as far out as with the lesser evolving technologies.

The program outlined herein provides a method to incorporate new technology in a prioritized manner. As a result, NASA will be assured that the latest technology is not wasted but is used to keep the United States' space program up-to-date and to make it a cost-effective leader, ahead of its international competitors. This Standard approach is essential. The recommended managerial approach for implementing research-mature hardware into flight applications is to provide a single management function for engineering and applied technology which is separate from research. The advantages are twofold. By incorporating engineering and applied technology into an office separate from research, internal office program competition between research and applied technologies will not occur. Also, the research environment is a different one than engineering and applied technology -- requiring a different professional focus. Both are equally valid, and one must not be implemented at the sacrifice of the other. Without research there will be little future for applied technology. Without engineering and applied technology, the United States' space program will lose out in its competitiveness struggle with aggressive international space programs. The program manager does not have to accept new technology at the expense of incurring high risks. Orderly transition using an Engineering and Technology Advancement Office is the answer.

A similar statement is made for combining engineering and applied technology into the development program offices. There, engineering and applied technology will compete with programs, and we may never escape the "catch-22" situation in dealing with programs.

Dedicated office roles have a stronger position in comparison with one having split responsibilities. Several high level reviews reached the same conclusion as discussed.

### 3. It will be expensive.

Response: The program is expected to provide real dividends as illustrated by Appendix A and as discussed in Section 11. Cost Benefits to Programs. There will be one qualification program, in-so-far-as components and subsystems are concerned, for all programs. There will be no need for the purchase of spares and any loss therefrom which can occur at the end of programs. An accounting system will be established to track hardware performance and used to show positive gains in performance. There will be an effective lessons learned program rather than a weakly defined data base which is not well utilized and is fragmented to the point of being inaccessible -- our current situation. Each program will not be required to test battery cells from the same lot as now is performed since the Engineering and Technology Advancement Office will serve all programs. Industrial competition will be an important aspect of this program to keep prices from becoming subject to the dictatorial drives of a single source supplier.

4. There will be performance penalties.

Response: This program changes the notion that an optimal program is comprised of the sum of mass-optimized components. The ETAO Program takes a total analytical systems approach instead. While some individual component mass penalties could be experienced, the overall system impact is positive. With a properly managed ETAO Program closely coupled with flight programs, performance penalties can be expected to be insignificant. The gains achieved with reductions in program costs are expected to make this worthwhile. Further, there will be additional margins in design where an over-design situation results. There will be Standards options at various performance levels to allow the designer options that closely match the performance desired. Incorporating the Standards at the beginning of the program will reduce penalties, if any, to a minimum. Through the proper planning of technology program requirements, we will develop and maintain a good set of design, performance, and operational requirements.

5. NASA should allow contractors the maximum latitude to perform their own practices.

Response: This program allows industry the option of coming in with an alternative proposed Standard design which they will have taken to a demonstrated flight readiness stage. At that time the hardware could be incorporated into the NASA Standard inventory.

There will be specifications written to which Standards are built and controlled, offering manufacturers the opportunity to participate in their initial development.

6. The approach of Standard platforms has been demonstrated to be of little value since many modifications are found to be essential to accommodate mission objectives.

Response: This proposal is structured to learn from that experience. For the proposed approach to be useful, versatility of flight vehicle design is essential to meet an ever changing set of mission objectives. Hence, this proposal emphasizes Standardized components and subsystems rather than completed platform assemblies. The mainstay of the Standard is at the component level. Next in emphasis is the subsystem level. This permits a more versatile management approach. Programs will still have the flexibility to employ Standard design options for various performance levels which can be selected from a catalogue. There is no proposed Standard platform, although this subject could and should be revisited as experience is gained with the program, a function of the Engineering and Technology Advancement Office.

7. Engineers like to "optimize" and to make changes to "improve" upon the product.

Response: A policy of "no changes" to Standards by individual programs will assure the financial benefits forwarded. The philosophy is: do it right the first time, involve all of the centers, and use lessons learned. Most importantly, keep this work under the control of one office, the Engineering and Technology Advancement Office, to assure compliance. Changes are expensive, as identified by several of the Agency review panels previously discussed.

8. What can go wrong?

Three major factors can cause this program not to succeed:

a.) The Engineering and Technology Program receives less than the full management commitment that it requires.

Without proper funding the program will suffer, as identified by the aforementioned GAO report, and the concept "proven" to not work. The question is, "What is the proper funding level? At this point in defining a program, little can be done to structure the budget other than to present the best available information. A rough estimate is shown in Section 11. One area that could use additional work is the ETAO operating budget. The program has a system established to quantify the benefits so that its impact on NASA programs will, and must, remain visible and accountable.

b.) Standards do not meet the expected performance requirements and cost savings.

One concern is the ability to predict ahead sufficiently to capture a complete set of realistic requirements. That concern remains whether or not an ETAO program is undertaken. One threat is that the cost of parts becomes unrealistically high. The solution is to have competitive bids for the Standards. As another option, depending upon the hardware, an ETAO decision, a GO-CO operation may be used as the more economical decision. As another option, one single Standard design for each hardware category is not necessarily proposed. Instead, a limited family of Standards, the quantity and magnitude of which is technology and hardware peculiar, may be the best approach – a decision which will have to be based upon studies by the ETAO. There is high confidence that the hardware will be developed into high quality products, provided that the manufacturing process is kept under strict control. The program has been structured to take those important matters into consideration and to develop management controls to prevent problems developing. Communications among the technical community must, as presented herein, be a strong part of the program.

c.) Programs decide to "optimize" on their own and continue to make changes.

If design, manufacturing, or operational changes are permitted, then the program will, in all probability, fail as a consequence of high costs and increased risk to component failure. That is the current situation and the reasons why the position is maintained herein that no true Standard has existed. The program is viable only if no changes are allowed once the hardware is proven. This is not to state that the ETAO would not conduct Product Improvement Programs – it would, but on a proven basis, for the entire Agency, prior to release for use.

9. Some refrain from the concept of a Standard because the concept is dictatorial.

Response: The strongest program is one which sells itself based upon its merits. Make a product that is sought after is the philosophy. There is always the risk of perception that the program constitutes a threat to engineering "individuality." The preferred approach to deal with the threat is to include the appropriate engineering participation and assuring management awareness of the program. An open program is essential.

10. The approach of Standard hardware and software removes responsibility from NASA's contractors.

This approach of Standard hardware and software takes nothing away from the responsibility of NASA's contractors. The Standard hardware and software performance have a pedigree well established. Terms of use of Standards are established by contract. The contractor is committed,

under contract, to use the Standards to the maximum extent feasible and to go through an acceptance and a subsystem/component review process. The Standard removes the pricing uncertainty element from component and subsystem design and development. The Standard approach, consequently, reduces the uncertainty and program risk to one of systems engineering and integration. "Low balling" of programs will as a result be discouraged; and cost overruns, as attributed to the factors addressed herein, will be drastically reduced. Fairness in the bidding process should be one result.

The bottom line is that NASA remains responsible for its programs. No manufacturer will warrant a mission based upon the success or failure of the company's products. The role of NASA is to assure that the proper management structure is in place to make the best equipment available for programs to safely meet mission success. The proposed approach accomplishes that management structure. Refer to Table 4. for a Summary.

Table 4. Summary of proposal cons and responses:

| Cons  | Response/Action   |
|---|---|
| 1. Low cost office "unsuccessful."<br><ul style="list-style-type: none"> <li>• one design</li> <li>• wide environmental requirements</li> <li>• inadequate acceptance</li> <li>• used common platforms</li> </ul> | <ul style="list-style-type: none"> <li>• Use multiple common design options.</li> <li>• Acceptable impact: limited launch vehicles; common operational environments.</li> <li>• Provide intercenter communications: technical steering committees.</li> <li>• Is accepted de facto: programs use hardware from other programs.</li> <li>• Use common "building block" components instead.</li> </ul>  |
| 2. Technology changes fast  | <ul style="list-style-type: none"> <li>• Establish system to implement new technology fast.</li> <li>• Avoid over commitment in rapidly evolving technologies (electronics): <ul style="list-style-type: none"> <li>-match planning with evolution rate.</li> <li>-many technologies not evolving fast.</li> </ul> </li> <li>• Prioritize incorporation of new technology.</li> <li>• Remove new technology inhibitors: <ul style="list-style-type: none"> <li>-place applied technology in dedicated office, technically focused and without competing funding interests</li> </ul> </li> </ul>  |
| 3. Expensive  | <ul style="list-style-type: none"> <li>• Provide real pay-back dividends: <ul style="list-style-type: none"> <li>-one qualification program.</li> <li>-program spares eliminated.</li> <li>-effective lessons learned.</li> <li>-competition.</li> </ul> </li> <li>• Reduce costs through new technology: <ul style="list-style-type: none"> <li>-make United States space technology more up-to-date: <ul style="list-style-type: none"> <li>-cost-effective leader.</li> <li>-ahead of international competitors.</li> </ul> </li> </ul> </li> </ul>  |
| 4. Performance penalties  | <ul style="list-style-type: none"> <li>• Analyze total systems costs: <ul style="list-style-type: none"> <li>-optimal program <math>\neq</math> sum of mass-optimized components.</li> <li>-optimal program = minimum cost-maximum performance of entire system.</li> </ul> </li> <li>• Make performance options available.</li> <li>• Integrate flight program requirements: <ul style="list-style-type: none"> <li>-develop/maintain good requirements.</li> <li>-small penalties.</li> </ul> </li> <li>• Provide program gain through lower program costs.</li> <li>• Increase design margin; reduce failures.</li> <li>• Incorporate Standards at program start.</li> </ul> |
| 5. Prevents contractors latitude  | <ul style="list-style-type: none"> <li>• Eliminate expensive "unique" contractor practices.</li> <li>• Permit alternative Standard designs from industry.</li> <li>• Include industry participation in Standards development.</li> </ul>  |

|   |   |
|---|---|
| 6. Modifications essential  | <ul style="list-style-type: none"> <li>• Permit versatile flight vehicle system design: <ul style="list-style-type: none"> <li>-meet ever changing mission objectives.</li> <li>-use common components and subsystems.</li> <li>-avoid common platforms.</li> </ul> </li> </ul>   |
| 7. "Optimize and technical changes"<br>-has always been the way of life   | <ul style="list-style-type: none"> <li>• Make no changes: Changes are expensive.</li> <li>• Do it right the first time.</li> <li>• Involve all centers.</li> <li>• Use lessons learned.</li> <li>• Manage by one office.</li> </ul>   |
| 8. What can go wrong?<br>a.) less than full commitment<br>b.) not meeting expected performance requirements and cost savings<br><br>c.) "Optimizing" and changes continue | <ul style="list-style-type: none"> <li>• Provide required funding.</li> <li>• Provide complete and realistic requirements.</li> <li>• Use competitive bids to reduce costs.</li> <li>• Develop management actions to assure performance.</li> <li>• Produce products to assure acceptance.</li> </ul>   |
| 9. Dictatorial  | <ul style="list-style-type: none"> <li>• Make this a merit-based program.</li> <li>• Remove concerns regarding threat to individuality: <ul style="list-style-type: none"> <li>-include appropriate engineering participation.</li> <li>-assure management awareness.</li> </ul> </li> <li>• Provide open, visible program.</li> </ul>  |
| 10. Removes contractors responsibilities  | <ul style="list-style-type: none"> <li>• Assure contractor responsibility: <ul style="list-style-type: none"> <li>-establish contractual commitment to use.</li> <li>-acceptance and subsystem/component review process.</li> </ul> </li> <li>• Develop rapport with system contractors: <ul style="list-style-type: none"> <li>-well established pedigree.</li> <li>-remove component/subsystem design/development pricing uncertainties.</li> </ul> </li> <li>• Increase contractor responsiveness: <ul style="list-style-type: none"> <li>-reduce uncertainties and program risk.</li> <li>-causes program emphasis on systems engineering and integration.</li> <li>-discourage "Low balling."</li> <li>-reduce cost overruns.</li> </ul> </li> <li>• NASA is responsible: <ul style="list-style-type: none"> <li>-no manufacturer warrants mission.</li> </ul> </li> </ul> |



## 11.0 COST BENEFITS TO PROGRAMS

The potential for savings and benefits to NASA from the ETAO are discussed. Attention is directed to the cost impact which common use elements can have on development programs without taking any credit for cost benefits for the program definition phase nor for operational cost reductions. *The program definition phase effects alone can have a profound impact since this benefit ripples throughout the program's life cycle.*

The first resource effort was to determine the annual expenditure for program development. Unfortunately, no pertinent resource analysis useful for this proposal could be found from the available data. The estimates below indicated an annual savings of ~\$2B. This was higher than expected. It is considered greater than the return that one could realistically expect. If we are conservative and state that \$500M to \$1B is saved, then clearly the program is worth implementing. Even a goal of \$100M is worth considering.

A thorough cost analysis using detailed resource data is a worthwhile endeavor but was beyond the efforts of the proposer working off duty and away from any data. A study team of several individuals working for months is the level of effort needed to better define the true budget potential.

The heart of the financial matter is how much can Standards save NASA over the course of a year. To answer that question we need to know all of NASA's program expenditures for hardware and software which can be made a Standard (Section 12) minus the costs to develop the Standards - amortized over all programs - and the costs to manufacture the standard hardware used. Program unique elements of systems are excluded, but the ETAO is expected to provide general guidance in the form of specifications and design guidelines such that program unique elements will receive engineering benefits and real cost reductions. Such savings will be difficult to estimate. Further, some benefits will be practically impossible to determine. For example, one cause of overruns has been attributed to the lack of stable program funding. Now, if this is a fully successful program and confidence is restored such that the Agency receives the needed resources for approved programs, then how can we attach a dollar benefit to that number?

Perhaps the most important part of this section is not so much the actual numbers derived, but the point is illustrated that we need to conduct relevant budget analyses to determine how and to what level we should provide resources to address problems. That designated allocation of resources to resolve problems at a level to provide a "designed return" is referred to here as an element of "cost engineering." That is, we need to trade off the investment such that it will be in compliance with the expected return.

The first objective of the cost analysis was to determine the approximate NASA budget for program developmental and qualification testing. Estimates were made based upon the FY92 (current) budget as submitted in the "FY 1993 President's Budget," Table 5.

Table 5. FY 1993 President's budget and estimated development budget (millions of dollars).

| <u>BUDGET LINE ITEM</u>                                | <u>1992<br/>CURRENT<br/>YEAR</u> | <u>PROPOSAL'S<br/>DEVELOPMENT<br/>BUDGET<br/>ASSUMED</u> |
|--|----------------------------------|--|
| <u>RESEARCH AND DEVELOPMENT</u>                        | <u>6850.8</u>                    |  |
| SPACE STATION  | 2028.9                           | 2028.9   |
| SPACE TRANSPORTATION CAPABILITY DEVELOPMENT            | 719.5                            | 719.5  |
| PHYSICS & ASTRONOMY                                    | 1047.3                           |  |
| LIFE SCIENCES  | 148.9                            |  |
| PLANETARY EXPLORATION                                  | 534.5                            |  |
| SPACE APPLICATIONS                                     | 998.1                            |  |
| SPACE SCIENCE AND APPLICATIONS                         | 2728.8                           | 2728.8   |
| TECHNICAL UTILIZATION                                  | 32.5                             |  |
| COMMERCIAL UTILIZATION OF SPACE                        | 115.1                            |  |
| COMMERCIAL PROGRAMS                                    | 147.6                            |  |
| AERONAUTICAL RESEARCH & TECHNOLOGY                     | 784.3                            | 78.43  |
| SPACE RESEARCH & TECHNOLOGY                            | 314.3                            | 31.43  |
| TRANSATMOSPHERIC RESEARCH & TECHNOLOGY                 | 5.0                              |  |
| SPACE EXPLORATION                                      | (5.0)                            |  |
| SAFETY, RELIABILITY, & QUALITY ASSURANCE               | 33.6                             |  |
| ACADEMIC PROGRAMS                                      | 66.8                             |  |
| TRACKING AND DATA ADVANCED SYSTEMS                     | 22.0                             |  |
| <u>SPACE FLIGHT, CONTROL &amp; DATA COMMUNICATIONS</u> | <u>5384.8</u>                    |  |
| SHUTTLE PRODUCTION & OPERATIONAL CAP                   | 1327.8                           |  |
| SHUTTLE OPERATIONS                                     | 2943.4                           |  |
| EXPENDABLE LAUNCH VEHICLE SERVICES                     | 195.3                            |  |
| SPACE COMMUNICATIONS                                   | 918.3                            |  |
| <u>CONSTRUCTION OF FACILITIES</u>                      | <u>525.0</u>                     |  |
| <u>RESEARCH AND PROGRAM MANAGEMENT</u>                 | <u>1577.6</u>                    |  |
| <u>INSPECTOR GENERAL</u>                               | <u>14.6</u>                      |  |
| TOTAL  | 14352.8                          | 5587.06  |

The \$5587.06M number included resources for non-developmental work. For example, the Space Science and Applications offices include mission operations plus research and analysis, a total of:

$$[\$380.8 + \$155 + \$88.8 \text{ (operations)}] + [\$70.5 + \$90.71 + \$75.1 \text{ (research \& analysis)}] = \quad (1) \\ \$624.6 + \$236.31 = \$860.91.$$

That number should clearly be subtracted from the \$5587.06M total for developmental costs. However, no developmental budget was allowed for the remainder of NASA's programs, obviously an incorrect assumption since a considerable sum is allowed for the Shuttle Program. But, rather than continue to make developmental cost assumptions about all other budget line items, which would be even more difficult to determine, the amount of non-developmental spending was assumed to at least be the equivalent of the developmental funds not included for the remainder of NASA's programs. Once again, these are estimates – because actuals are not available.

The accumulated budget for development and qualification testing summed over all NASA programs is our target and is defined as "Budget Availability."

$$\$5587.06/\$14352.8 \approx 40\% \quad (2)$$

That 40% term shows the magnitude of resources which can be considered for cost savings. These are "normalized" figures in that they are the sum of all program activities, not any specific program. Actuals may vary from time-to-time and from program-to-program. This determination, thus, reflects the broad NASA-wide perspective, not a program specific application.

Upon the receipt of better data, the numbers can be adjusted to more accurately reflect the actual developmental costs.

But the principle remains: effect tremendous savings by performing one qualification program, by having a common set of spares, by leveraging technology advantages using new research mature developments, and by avoiding cost delays which occur from qualification test failures and from new programs experiencing over and over the lessons learned. The goal is to increase mission reliability at a substantial cost savings.

To derive the budget for NASA's aggregate development/qualification testing, the analysis commences with the NASA budget, \$14B (FY92) Table 6a, Line Item 1.

Table 6a. Program Cost analysis.

| Line Item                                  | Cost Basis       | Cost factor    | Availability    |
|--|------------------|----------------|-----------------|
| <b>BUDGET AVAILABILITY</b>                 |                  |                |                 |
| 1. NASA Budget                             | \$14,000,000,000 |                |                 |
| 2. Developmental programs allocation       |                  | 40%            |                 |
| 3. Developmental costs per annum           | \$14,000,000,000 | x 0.4 =        | \$5,600,000,000 |
| 4. Component/subsystems allocation         |                  | 50%            |                 |
| 5. Apportionment to flight hardware        | \$5,600,000,000  | x 0.5 =        | \$2,800,000,000 |
| 6. Adjustment                              |                  | 25%            |                 |
| 7. Cost savings development/qual avoidance | \$2,800,000,000  | x (1 - 0.25) = | \$2,100,000,000 |

The assumption is made, as shown in equation (2) above, that 40% of the budget is devoted to program development, Line Item 2, for a total expenditure of \$5.6B, Line Item 3. Of that amount, we further assume that half of the funds are spent to conduct and support the development/qualification programs, Line Item 4, for a total of \$2.8B, Line item 5, spent per annum on program development/qualification testing of hardware (non-system level expenditures). The remainder is spent for system design, system level testing, flight hardware, operations, plus overhead, profits, etc. We make a 25% adjustment to allow for certain program unique considerations where program unique elements are necessary, Line Item 6.

According to the results of this brief analysis, the Agency could save annually \$2.1B, Line Item 7, if a sufficiently strong Standards program is implemented whereby flight and ground programs can nearly eliminate component and subsystem development and qualification testing. The worst scenario would be to provide inadequate support/resources and then conclude that the concept lacks merit.

Now an important thesis of this proposal is that complementary synergistic savings will result as a virtue of the benefits from such an engineering and applied technology effort. These are listed in the "Benefits" section of Table 6b.

Table 6b. Program cost benefits - a return on the ETAO investment.

| BENEFITS (avoid):                               |                 |        |                 |
|---|-----------------|--------|-----------------|
| 1. Program schedule slips                       | \$5,600,000,000 | 6.00%  | \$336,000,000   |
| 2. Repeat design/test due to qual test failures | \$5,600,000,000 | 3.00%  | \$168,000,000   |
| 3. Low balling                                  | \$5,600,000,000 | 2.50%  | \$140,000,000   |
| 4. Lack of technical understanding              | \$5,600,000,000 | 1.00%  | \$56,000,000    |
| 5. Incorporation of advanced technology         | \$5,600,000,000 | 1.00%  | \$56,000,000    |
| 6. Spares provisions                            | \$5,600,000,000 | 2.00%  | \$112,000,000   |
| 7. In flight failures                           | \$5,600,000,000 | 10.00% | \$560,000,000   |
| 8. Other  | \$5,600,000,000 | 0.50%  | \$28,000,000    |
| 9. Total: costs returns due to "Benefits"       |                 |        | \$1,456,000,000 |

We now discuss the above rationale and the 8 aforementioned budget stresses, section 8.1, to better understand the magnitude for potential savings, one judgment for initiating the program and the basis for an ETAO funding level.

The schedule slip cost factor, Line Item 1, Table 6b, assumes a typical 3-4 year program will slip one year (25%), the costs of which when amortized over the four year developmental time is ~6%. The analysis assumes that the delays will cost the program at least that amount just to support the "standing army," exclusive of the costs to fix the problem(s), redesign, retest, change in the paper work, etc.

Programs incur significant penalties on resources due to the impact of failures occurring while the hardware is in development. Here, we state that a failure rate of 1 in 10 is not unreasonable. Since development testing costs are non-linear over the program's life, a normalized 3% per annum, Line Item 2, rate savings due to the use of already qualified hardware is claimed.

Low-balling by contractors can range from 0% for a fixed price contract to several hundred percent increases as contractors recoup (planned) losses in the bidding process through changes. Standards will assist in the reduction of costs by providing well defined hardware for contractors to use. There will be less fuzziness attached to at least the extent of the applications of Standards. Here, we arbitrarily assign a 10% value as a total average impact across all programs which, amortized over a four period, is 2.5%, Line Item 3.

Lack of technical understanding, Line Item 4, was mentioned in Section 8.1 as a prime contributor to failures causing redesigns and retest from development through qualification. Failure to meet mission objectives was the most costly consequence. In the case of that particular technology, pyrotechnics, deaths also resulted. A 1% allowance was made.

By incorporation of advanced technology into the inventory of Standards, there is an implied benefit of getting more for less. This benefit is simply shown as a 1% improvement, Line Item 5.

Spares procurements will no longer be required where Standards can be used, a total of 8% for the program is shown. This provides a savings per annum of 2%, Line Item 6.

The negative impact of in-flight failures is very difficult to quantify. First, there is the real dollar impact of the losses. Second, there are the additional costs due to efforts required to

recoup losses, operational workarounds, loss of mission objectives, etc. But perhaps more important is the third, the loss of public confidence and Agency prestige from such failures. The psychological aspects impact the very future of space and aeronautics research and hence technological advancements in those areas. A fourth category is those changes where the system overreacts to prevent future occurrences. Over-reaction affects all on-going and future programs.

Avoidance of failures has the positive benefits of reduced need for specialized, ad hoc failure investigations and reviews, oversight roles, added inspection, and related topics. Using a Standards approach, the Agency is in the position of concentrating its resources, permitting a direct focus on the NASA Standards hardware. Thus, there are less administrative expenses, G & A, profits, etc. In the course of system design, programs in the future may be able to count on high quality pedigree and highly reliable products sufficiently that redundant elements may be reduced or eliminated, which will effect significant savings.

Some programs experience no significant failures whereas others such as Challenger, Hubble (not truly a failure since very valuable science is being gathered but nevertheless a "failure related experience" since NASA is spending significant resources to correct the error), Apollo 204 fire, – have cost the Agency billions of dollars. To address the problem illustrated by that Galileo antenna failure to deploy, standard mechanisms are not necessarily proposed; but this design issue is addressed by two methods. (1) A design Standard can be developed, and (2) the engineering support as discussed in the Charter will provide a stronger design review process.

The ETAO and standards may not eliminate all failures, such as those major program failures (Apollo and Challenger) mentioned earlier; but through the "other" support provided to NASA's programs, topic "C" in the Charter, there will be a positive benefit toward reducing failures. Where Standards will directly benefit is with regard to recent failures, such as those now being experienced with gyros and batteries, for example. To provide a value, we arbitrarily assign a 10% number Line Item 7. There is no way that one can assess the negative psychological impact – i.e., loss in confidence by Congress, the Administration, and the public when failures are reported. Clearly this has the potential for being overwhelming beyond any number assigned. The contrast between a "success" article and "failure" article is illustrated by the *Washington Post*, January 5, 1993 front page. In one case we accomplished our mission; in the other case, we did not.

For the "Other" category identified above, a 0.5% saving is used, Line Item 8. The Benefits total \$1.5B, Line Item 9.

One may look at these numbers and state that they are too high. Perhaps they are and the challenge is there to address. The criteria have been discussed: more detailed cost analyses should be conducted. The basic budget numbers presented in Table 5 (and a first line break-down) were all that could be found. On the other hand, we still pay for earlier problems such as Challenger and cost overruns, which are not included.

The question now before us is, "What does it cost?" The response is as much or as little as desired. A reasonable approach would be to select a modest budget to commence using technologies that are known to have a great need and to provide a quick return. In the formative stages, key planning would be quickly developed to determine the best technologies to pursue. This planning should be accomplished within a year. Because it is clear that the return will be significant, a large initial budget would produce benefits sooner by bringing Standards on line more rapidly. Hence, there is an early ramp-up in the budget. After technologies are brought on-line, then we can expect to see a decline.

As a couple of quick turn-around examples, a laser initiated ordnance capability could be provided. To flight qualify and demonstrate that system would be expected to cost several million dollars. A space qualified, high-performance laser gyro would require ~\$20M to space qualify. A large portion of the funds would be expected to be used for propulsion. Standard liquid propulsion system components would be expected to cost \$100M to \$300M. Hybrids should be included, and the industry would cost-share, offering good leveraging.

A suggested spending rate for a reasonable approach to provide quick returns and to be compatible with NASA's two year planning process is illustrated as shown in Fig. 16.

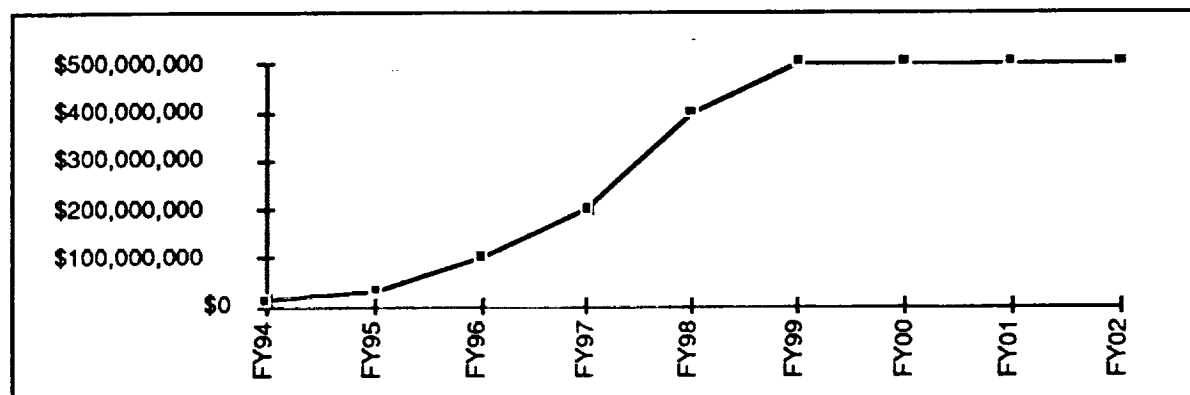


Fig. 16. Suggested budget consideration for the Engineering and Technology Advancement Office.

A number of \$500M was selected from the FY92 budget. In that year, the developmental resources was \$5.6B. To obtain a program-normalized value for development, we divide that number by the number of major R&D programs to obtain a rough magnitude estimate. It appears from the budget submittal that 12 major programs can be considered under development, or \$470M/program. Hence, a value of \$500M was selected as the first-cut ETAO budget. Obviously, considerable effort can be expended to refine that number, a task well beyond this proposal. Clearly, some developmental elements for programs have been included in using that costing method which will not be assisted by an advanced technology development programs, such as Space Station which is presumed to have much of its resources dedicated to the design, fabrication, and qualification of unique structure. There are Space Station Program elements that could be readily aided by Standards, however. Budgets for hardware and software elements in other NASA programs that would stand to benefit from the Standards approach have not been shown and should be included as part of the overall costing summary. Table 1c presents the cost summary as determined up to the point of this proposal.

Table 6c. Program cost summary.

|  |  |
|--|--|
| <b>INVESTMENT</b>  |  |
| 1. Budget of Engineering and Technology Advancement Office | (\$500,000,000)                                    |
| 2. Administration costs                                    | (\$1,000,000)                                      |
| 3. Total expenses  | (\$501,000,000)                                    |
| 4. Net Savings   | Savings: \$2100 - expenses (\$501) \$1,799,000,000 |

A bold funding approach would be to start quickly with a large budget to take advantage of the payoffs more rapidly. After the program has implemented well-defined Standards, the budget

would then decrease. This is expected to typically require five years after full funding is reached, but the specifics are directly related to each technology.

## 12.0 LIST OF CANDIDATE ITEMS FOR STANDARDS

The list below represents potential candidates for Standardization. Both subsystems and components are shown. There can be anticipated several Standard design options for any given function, such as several Standard thruster sizes, for example. The inventory will be determined by the Engineering and Technology Advancement Office based upon analyses of program requirements.

1. Power system
  - batteries
    - cells
  - controllers
  - solar cells
  - converters
  - inverters
  - control software
  - pressure regulators
  - tanks
  - check valves
  - relief valves
2. CPU's (several)
3. Data
  - storage (tape, solid state digital)
  - multiplexer-demultiplexers
  - control software
4. Communications
  - receivers
  - transmitters
  - transponders
  - control software
  - antennas
  - amplifiers
5. Guidance/controls
  - star trackers
  - gyros
  - IRU/IMU
    - accelerometers
  - servomechanisms
  - control moment gyros
  - magnetic torquers
  - momentum wheels.
6. Propulsion: primary and RCS
  - thrusters
  - primary propulsion engines
  - solids
  - hybrids
  - electric
7. Pyrotechnics
  - initiators
  - detonators
  - separation systems
  - pin pullers
  - frangible nuts
  - frangible bolts
8. Electronic piece parts
9. Wiring
10. Mechanical parts/mechanisms
11. Fiber optic components  
(connectors, cable, diodes, etc.)
12. Sensors
  - laser optical systems
  - vehicle/system health monitoring
  - common use science instruments
  - detectors for science.
13. Biomed technology
14. Software
  - designs and applications: TBD



### 13.0 FUNCTIONS AND PRIORITIES

A large part of this program must necessarily be devoted to the most critical, high leverage payoff hardware. A major task during the first two years of the ETAO will be to determine that priority. It can be reasonably anticipated the office will be expected to devote considerable resources to propulsion. This question of priority is important now because the decisions on hardware priority will be a very large factor in the determination of the ETAO budget, clearly an important aspect of this proposal.

#### Propulsion:

There are many reasons for the strong consideration of propulsion:

1. mission enabling technology. Without economical high quality propulsion capabilities, programs will be very constrained. Without propulsion, we go nowhere. Propulsion determines mission economics and capabilities.
2. long lead time to develop. The SSME contract with Rocketdyne lead the initiation of the Rockwell contract for the Orbiter and the integration contracts by several years.
3. expensive development, design, testing, and manufacturing costs.
4. high operational costs.
5. most dangerous. The Challenger attests to that fact.
6. least safety margin.
7. high inherent energy content.
8. most politically threatening to NASA. In the event of another Challenger, in today's environment, serious doubt could result in the safety of the United States only manned launch vehicle. That could deal a major blow to manned space travel and the future of NASA's current plans because that failure would have very serious implications upon any manned orbiting laboratory. To replace the Shuttle with another design could result in a set back of 8 to 10 years.
9. receives proportionally the least budget attention because it is perceived as research mature.

#### Safety:

Relatively little development funding goes into safety technology. The main emphasis has been to prevent accidents by procedure, the weakest means of hazard abatement. The strongest is hazard elimination, and that achievement can only be accomplished through technology advancements, not through adding requirements. A considerable effort is expected to be devoted by the ETAO to safety, perhaps one of the most neglected focused technology activities. In terms of importance in preventing a broadened access to space, safety is second only to economics.

Economics:

Considerable effort is also expected to be devoted to this important technology factor for space.

The Advisory Committee on the Future of the U.S. Space Program expressed a priority setting "Among the more critical technology topics that must be pursued are propulsion and aerodynamics including flight evaluations, advanced rocket engines that do not detrimentally impact our environment, aerobraking for orbital transfer, long duration closed ecosystems and life support systems, nuclear electric space power, space tethers and artificial gravity, automation and robotics, information management systems, sensors, electric power generation, radiation protection and materials and in-space materials processing." (Ref. 21 p 31)

Some of those technologies still belong in the research organization whereas some are critical for an Engineering and Technology Advancement Office.

## 14.0 OPTIONS

The program fact is: each program conducts its own development and qualification program, without regard for other programs, but with relevance to the NASA mission. Serious problems exist with keeping down costs, meeting mission program budget, and meeting mission objectives.

The options are fundamentally three: (1) maintain the current management approach where program "individuality" is the method and substantial civil service manpower is devoted to contract monitoring, (2) change from a single program "individual" approach to this proposal - an integrated NASA-wide engineering approach, (3) turn over the total responsibility to a contractor and offer financial incentives. The first option is unacceptable because of the problems which have accumulated. The second option has many advantages with addressing the problems as outlined in this document, but implementation requires a cultural change. The third, in the opinion of the proposer, will lead to higher program costs, but is an easier path to follow.

An educated, highly experienced buyer is one of the best assurance policies to achieve cost control and quality products. The thesis of this proposal is that experienced NASA civil servant staff has decreased significantly decreased from the "hands-on" capabilities to one of increased contract monitoring. A recent study performed for the Administrator concurs. (Ref. 26) For additional evidence, consider the NASA rationale for the Shuttle toilet cost overrun, Ref. 10 p. 22, item 2, "acceptance of contractor recommended improvements" (changes). That is considered to be an implied admission that the hands-on capability is lacking. Option 3 rapidly accelerates the path of a hands-off philosophy. Option 2 turns the table.

The recommendations made and actions taken as a result of all the aforementioned reviews have not resolved the problems; and indeed, if anything they would appear to have increased. That leaves the second option. Implementation will require a cultural change, primarily from one of an "individuality" approach to an integrated, cooperative effort. That may be the most difficult challenge for NASA to meet in this proposal.

## 15.0 ACCOUNTABILITY

This program promises to deliver higher mission success at lower costs. Clearly an accounting system is warranted to measure the degree of success achieved. Corrective measures can be instituted to keep the program on the right track. The timetable to demonstrate success will not be quick. Improvements should be forthcoming after several years on technologies amenable to quick improvements. Others such as propulsion will take longer. If the program's results are not sufficiently high after approximately 10 years of full funding, then the program should be terminated.

One measure of success will be a reduction in overruns. Another will be a decreased incidence of failures. Both are easily tractable and quantifiable numbers. As mentioned at the beginning, there are overrun rationale which this program does not address. Hence, caution must be exercised in evaluating the accountability achievements. We wish to avoid curtailing a useful approach that is due to factors which are beyond the assistance of an ETAO.

## 16.0 RECOMMENDED NEXT STEPS

- 1.) Proceed with a program definition task to implement an Engineering and Technology Advancement Office (ETAO): Assemble an *Engineering and Technology Advancement Working Group* having representatives from each center to establish and plan the office and to further establish a budget, considering the issues raised in Section 11. Using a staff of 2-3 Headquarters engineers, initiate several pilot Standard demonstrations, ones that can produce relatively quick results. By the end of the first year, complete an Engineering and Technology Strategic Plan for senior management review. By the end of the second year complete the determination of NASA's requirements to permit establishing program priorities and perform a Standard pathfinder project.
- 2.) Establish responsibilities in the ETAO to include:
  - a.) NASA-wide Standards, including a Product Improvement Program and configuration management system,
  - b.) a low risk system to transition research-mature technology to flight program status,
  - c.) a system to rapidly transfer applied technology from the laboratory to the market place.

## 17.0 SUMMARY

This proposal actively addresses the key issues facing NASA: cost overruns, high development costs, schedule delays, and high operational costs. The new proposed objective focuses on accomplishing NASA goals (payloads) rather than on the tools (the equipment to deliver the payloads). This proposal redefines the business of NASA and charts a new course. Change is mandated. The question is, "Are we up to acceptance of change?"

### PROPOSAL PROS

1. enhances safety, reliability, mission success, and operations.
2. reduces technical problems.
3. reduces cost increases.
4. reduces total program costs regardless of overruns.
5. reduces schedule risk.
6. keeps programs with current technology at low risk.
7. rapidly transfers technology from the laboratory to the market place.
8. allows us to determine our fate and makes the NASA engineering staff an educated buyer.
9. provides strong participation with industry and academia.
10. is a customer-oriented system.
11. provides hardware and software qualified to meet a wide range of mission requirements.
12. uses an integrated engineering approach to solve engineering problems.
13. identifies and resolves common technical issues across NASA.
14. markets NASA's resources to increase the United States' economic position in an ever increasing international competitive market place.
15. collects technical lessons learned and incorporates that experience base into subsystem designs and processes via well-planned, systematic design, test, and manufacturing approaches.
16. assures current up-to-date hardware through a Product Improvement Program.
17. aids all four phases, Phase A through D.
18. provides mass buy price advantages.
19. provides Standards which can be readily obtained off-the-shelf or by procurement from certified vendor(s).
20. produces products which are applicable to a wide variety of programs without requalification.
21. has frozen design and frozen manufacturing process to maintain qualification status.

22. provides for the much needed hands-on NASA experience.
23. provides a means for NASA engineers to become better educated buyers, a strong tool for effecting future cost reductions.
24. provides technical consistency across all NASA centers.
25. avoids waste from the purchase of spares and expensive program delays due to the lack thereof, thereby effecting significant savings.
26. establishes common design, development, and qualification specifications for use across NASA.
27. focuses on specific applications and problems.
28. allows programs greater opportunity to work on NASA goals rather than become heavily involved in hardware problems. Programs could then focus on meeting mission objectives rather than upon devoting staff and financial resources to assuring that system components are working properly.
29. opens new markets in order for the United States to maintain its economic strength in the wake of the end of the Cold War and from the increasing international competition.
30. creates an efficient and effective partnership with industry to assure that NASA's technologies rapidly transgress from the laboratory to the market place.
31. performs as a service organization.
32. stimulates intercenter cooperation.
33. makes use of university resources to assist.
34. provides for NASA-wide engineering state-of-health support.

#### PROPOSAL CONS

1. requires a change in the culture to implement.
2. may require small performance and mass compromises.
3. limited where technology changes fast.
4. requires acceptance by all.
5. requires advanced planning.
6. requires a "no-change" attitude in dealing with program components.

## APPENDIX A

### EXAMPLES

#### A. Pyrotechnics.

To illustrate the principles discussed in this proposal and their merits, consider the "NASA Standard Initiator" (NSI). The NSI is the best "living" example which illustrates the use of a Standard as a management approach.

Let us assume that there is no Standard program and that a new developmental flight vehicle program requires ten different pyrotechnically initiated devices. Potentially ten different subcontractors will have the responsibility for ten separate pyrotechnic devices, and there could potentially be up to ten different procurements to perform the same function (initiation of the pyrotechnic devices) across the program. Each requires a separate qualification test program for each of the ten separate initiators - the common hardware thread among pyrotechnic devices. In addition, there will be ten different sets of spares to purchase and to maintain. Multiple initiator designs were used early in NASA's history.

The Apollo program took the approach of qualifying one initiator, the Apollo Standard Initiator (ASI), for all Apollo pyrotechnic applications; and the old management approach was changed. When the NASA Standard Initiator (NSI) was developed from the Apollo Standard Initiator, a multi-program NASA-wide Standard initiation capability was provided, making one Standard initiator for use across all NASA programs. For payloads, this approach has the distinct advantage of no longer requiring the qualification of a new and different initiator to fly aboard the Shuttle, a very expensive proposition considering the safety implications. Now we are in the situation where a new qualification test program does not have to be performed for each payload with all of the problems that qualification can entail. Further, there is the data base from over a 25-year period which no program can afford to independently develop.

The Standard is a very user friendly management tool - one of great importance to NASA. The responsibility of Headquarters is to step into the broad perspective of the NASA-wide issues and to resolve them. Hence, the above constitute rationale for Standards using one focused technology as an example to illustrate the principles involved in this proposal.

#### B. Hybrids

Hybrid propulsion systems serve as a different example of illustrating the need for the Engineering and Technology Advancement Office. The 30-year old technology has been demonstrated but has not been developed for flight use. The capability is one which would enhance the safety of programs. If NASA develops a hybrid solid motor, thrust termination would be possible, preventing vehicle breakup. Even if breakup started to occur thrust termination permits safe bailout of the crew. The small developmental cost will be considerably less than the costs which the result could bring. In addition, there would be a performance gain which would pay for the program. High leveraging with industry would make this a particularly attractive investment.



## REFERENCES

- <sup>1</sup> *Washington Technology*, "Foreign SATs Lead U.S.," Randy Barrett, p. 29, February 11, 1993
- <sup>2</sup> "Satellite Communications in Europe, Russia, and Japan, NASA/NSF Conference, Washington, D. C. February 5, 1993.
- <sup>3</sup> *Washington Post*, "NASA's New Space Toilet: \$30 Million Up the Drain," Kathy Sawyer, front page, January 5, 1993.
- <sup>4</sup> *Washington Post*, "Space Station Overruns Larger Than Expected," Kathy Sawyer, page A3, January 31, 1993.
- <sup>5</sup> *Space News*, "Further Overruns Threaten Station," Andrew Lawler, v.4, #5, front page February 1-7, 1993.
- <sup>6</sup> *Washington Post*, "Satellite Finds 'Dark Matter' That may Bind the Universe," front page, Kathy Sawyer, January 5, 1993.
- <sup>7</sup> *Washington Post*, "Climatology: Space Data Indicates Rivers in the Sky," page 2, Kathy Sawyer.
- <sup>8</sup> *Space News*, February 8-14, 1993, "Clinton Urged to Cancel Station," v.4, #6, front page, Andrew Lawler, January 25, 1993.
- <sup>9</sup> Bement, L. J., "Pyrotechnic System Failures: Causes and Prevention," NASA TM-100633, Langley Research Center, Hampton, VA, June 1988.
- <sup>10</sup> *NASA Program Costs, Space Missions Require Substantially More Funding Than Initially Estimated*, GAO/NSIAD 93-97 December 1992
- <sup>11</sup> *NASA's Management of Its Research and Technology - A Study of the Process -*, Submitted to the Associate Administrator, The Management Study Team, TL 521.312.N38 1977, March 29, 1977.
- <sup>12</sup> "Subcommittee on Science, Technology and Space, Committee on Commerce, Science and Transportation, United States Senate, Dr. Donald P. Heath, TL 521.312.H43 1981, April 27, 1981.
- <sup>13</sup> *Civilian Space Stations and the U.S. Future in Space*, Congress of the United States, Office of Technology Assessment, Library of Congress catalogue card number 84-601136 November 1984.
- <sup>14</sup> *Planetary Exploration Through Year 2000, a Core Program*, U.S. Government Printing Office, Washington 1983.
- <sup>15</sup> *Report of the Presidential Commission on the Space Shuttle Challenger Accident*, NASA, Washington June 6, 1986.
- <sup>16</sup> *Pioneering the Space Frontier, The Report of the National Commission on Space*, Bantam Book, May 1986.
- <sup>17</sup> *NASA, Leadership and America's Future in Space*, A Report to the Administrator, Dr. Sally K. Ride, TL 521.312.R53 August 1987.
- <sup>18</sup> *NASA's Space Research and Technology Program, Report of a Workshop*, Aeronautics and Space engineering Board, Washington, National Academy Press, 1983.
- <sup>19</sup> *NASA Management Study Group-II, Effectiveness of the Headquarters, National Aeronautics and Space Administration*, S. C. Phillips, TL 5521.312.E445 1988, February 17, 1988.
- <sup>20</sup> *1989 Long-Range Program Plan*, NASA, Washington, D.C.
- <sup>21</sup> *Report on the Advisory Committee on the Future of the U.S. Space Program*, Norman R. Augustine - Chairman, TL 521.312.R47, 1990.
- <sup>22</sup> *America at the Threshold, America's Space Exploration Initiative*, TL 799.M3 S95, 1991.
- <sup>23</sup> "NASA-'Roles and Missions' report," J. R. Thompson, TL 521.312.T56 1991, September 8, 1991.

<sup>24</sup>"A Strategy of Cost Control for Mariner Venus/Mercury '73," John R. Biggs and Walter J. Downhower, *Issues in NASA Program and Project Management*, NASA SP-6101 (05), TL 521.312.I77, 1992.

<sup>25</sup>*1991 Integrated Technology Plan for the Civil Space Program*, Office of Aeronautics and Space Administration, Washington, 1991.

<sup>26</sup>"Maintaining the Program Balance, A Report for the National Aeronautics and Space Administration," National Academy of Public Administration, Finger, PM TL 521.312.N374 1991.

<sup>27</sup>"The Shuttle: A Balancing of Design and Politics," *Issues in NASA Program and Project Management*, NASA SP-6101 (05), TL 521.312.I77 1992.


<sup>28</sup>*Photonics Spectra*, "Fiber Optic Gyros Help Tokyo Drivers Navigate," p. 18, January 1993.

<sup>29</sup>Transmittal from Dr. Cox, February 26, 1993.



# Suggestion

**NOTE: Please refer to instructions on reverse before completing**

|   |  |                                    |                           |
|---|--|------------------------------------|---------------------------|
| SUGGESTER'S NAME<br>Norman R. Schulze   |  | OFFICE CODE<br>QE                  | TELEPHONE NO.<br>358-0537 |
| INSTALLATION/FACILITY<br>Headquarters   |  | BUILDING AND ROOM NO.<br>Room 5Y55 |                           |
| POSITION TITLE<br>AST, Manager, Flight System Programs  |  |                                    | GRADE<br>GS-15            |
| NAME OF SUGGESTER MAY BE MADE KNOWN: <input type="checkbox"/> NO <input checked="" type="checkbox"/> YES  |  |                                    |                           |
| THE ACCEPTANCE OF A CASH AWARD FOR THIS SUGGESTION SHALL CONSTITUTE AN AGREEMENT THAT ITS USE BY THE UNITED STATES NOT FORM THE BASIS OF A FURTHER CLAIM OF ANY NATURE UPON THE GOVERNMENT BY ME, MY HEIRS OR ASSIGNS |  |                                    |                           |
| SUGGESTER'S SIGNATURE<br>  |  |                                    | DATE<br>3/28/93           |
| SUBJECT/DESCRIPTION OF SUGGESTION<br>Engineering and Technology Advancement Office  |  |                                    |                           |

PRESENT METHOD OR CONDITION *(Continue on separate sheets if necessary)*

Technical engineering problems with programs are resulting in program overruns and less than the desired performance. There is a void in the NASA management structure which prevents the systematic resolution of these on-going engineering problems. This is a need which has existed for decades.

Please refer to the attached proposal for further details.

SUGGESTION *(Describe specific recommendation and manner in which it should be implemented. Also, describe benefits and estimate savings which might be derived. Continue on separate sheet and attach pictures, forms, drawings, etc., if necessary)*

Establish a new Engineering and Technology Advancement Office as discussed in the attached proposal entitled, "Engineering and Technology Advancement Office, A Proposal to the Administrator."

I specifically request a review of this proposal by the Administrator since this subject requires a top level decision.

There has been a wide peer review conducted by technical staff at Headquarters, the Field Installations, and others in industry as discussed in the document.

LOCATION WHERE SUGGESTION IS TO BE APPLIED  
Throughout NASA

## PERSONNEL USE ONLY

|  |                   |
|--|-------------------|
| TYPE (Check)<br><input type="checkbox"/> GROUP <input type="checkbox"/> INDIVIDUAL | CONTROL NO.       |
| TYPED NAME AND SIGNATURE   | DATE ACKNOWLEDGED |

